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MERCURY POLLUTION

IN THE

WABIGOON-ENGLISH RIVER SYSTEM

A SOCIO-ECONOMIC ASSESSMENT OF REMEDIAL MEASURES

JANUARY, 1986

Ministry
of the
Environment

Ontario

The Honourable
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Minister

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Deputy Minister

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by

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January 1986

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ACKNOWLEDGEMENTS

The author wishes to thank Kerstin Skold-Mohammed, Corporate Policy and Planning, Ontario Ministry of the Environment, for assembling data on Ontario fish harvests and demographics in the Wabigoon-English system.

Messrs. Bill Creighton and John Parks, MOE, Thunder Bay, provided guidance concerning the intricacies of mercury transport, as well as useful comments and suggestions that improved the study.

Mr. D.B. McGregor and the staff of the Kenora District Office, Ministry of Natural Resources, provided maps of the fishing lodges and additional data on sport fishing in the system.

A special thanks to Christine Lucyk, Carl Griffith and David Evans, Corporate Policy and Planning, Ministry of the Environment, for assistance in editing the final report into its present form.

Messrs. André Castel and Walter Smithies, Corporate Policy and Planning, Ministry of the Environment, also provided many suggestions and comments during the final editing of this report.

Finally, to former and present word processing staff, who suffered the typing of this report through its evolution, my profound gratitude.

Any errors or inaccuracies that remain are, of course, the responsibility of the author.

EXECUTIVE SUMMARY

MERCURY POLLUTION IN THE WABIGOON-ENGLISH RIVER SYSTEM -

A SOCIO-ECONOMIC ASSESSMENT OF REMEDIAL MEASURES

A joint Ontario-Canada Steering Committee, which directed a study of mercury contamination on the Wabigoon-English River System, has recommended remedial measures that could accelerate the observed decline in mercury contamination in fish. Dredging of the contaminated sediments in the Wabigoon River between Dryden and Clay Lake, together with covering of the contaminated sediments in Clay Lake ("sediment mixing"), are the preferred remedial actions.

A comprehensive socio-economic assessment of the proposed remedial actions is presented in this report. This study was commissioned by the Northwestern Regional Office of the Ministry of the Environment and complements several other Provincial and Federal studies which address the scientific aspects of the issue.

Specific objectives of this study are:

- to identify and quantify, to the extent possible, the potential beneficial consequences of the proposed remedial measures and associated economic values;

- to specify which agencies, groups and/or regions would enjoy the benefits or bear the costs; and

- to compare the benefits and costs in an appropriate manner.

A key finding of the study is that any benefits would only be derived if the remedial measures caused an acceleration of the natural decline in the levels of mercury contamination in fish that has been occurring over the past decade. Uses and activities associated with the rivers and lakes that do not involve fish, including the use of the water for drinking, are not affected by the mercury contamination.

Another important finding is that, despite the extensive investigations carried out by federal and provincial scientists, reliable estimates could not be provided:

- of the rate of decline in mercury concentrations in different fish species due to the remedial actions, and

- of when, if ever, average mercury concentrations in each fish species would achieve a desired level (e.g., 0.5 ppm for commercially caught fish).

Potential public benefits of the recommended remedial actions and their beneficiaries are identified including:

1. Reduced **physical** and **mental health risks** to the Native People of the Grassy Narrows and Whitedog Reserves.

2. Increased **commercial fishing** opportunities and catches for the Native People of Grassy Narrows and Whitedog.

3. Increased **food-fishing** opportunities and catches for the Native People of Grassy Narrows and Whitedog.

4. Increased enjoyment of **sport fishing** by anglers who already fish in the area or the attraction of **new anglers** to the area. Possible increased **revenues** and profits to tourist services such as fishing lodges and camps.

5. **Non-user** benefits in terms of increased satisfaction for the citizens of Ontario and Canada of knowing that the mercury contamination has been reduced and that the other benefit categories have been achieved.

6. **Social benefits** in terms of reduced social disruption to the Native People of Grassy Narrows and Whitedog.

These benefits can be realized only if the remedial actions are successful in accelerating the reduction of mercury concentrations in fish.

The proposed dredging project would cost about $20 million spent over 5 or 6 years, and would be borne by the Provincial Government. Sediment mixing in Clay Lake would cost an additional $4.5 million if the dredging equipment were already at the site.

Expenditures on dredging would generate some employment and income in the region. These effects are not considered benefits of the program because they are only temporary and are accompanied by offsetting economic impacts elsewhere.

Quantitative estimates of the potential benefits and their monetary values were developed for commercial and food fishing. Data are insufficient to estimate the quantitative benefits (and their monetary values) associated with reduced health risks, sport fishing and tourist services. Nevertheless, it was clear that most of the potential benefits would accrue to the Native People at the Whitedog and Grassy Narrows Reserves.

Any benefits derived from reduced mental and physical health risks are limited to the people at Grassy Narrows and Whitedog. These potential benefits are limited further by the fact that many of the people are suffering from past contamination and the likelihood of future contamination appears to be diminishing as mercury levels in fish decline.

Further study would be needed to determine whether existing sports anglers would gain added satisfaction or whether new fishermen would come to the area if mercury levels in fish declined. It is not clear whether the tourist camps and lodges would gain any extra profits as a result of a successful remedial program.

Rehabilitation of the Wabigoon-English System could contribute positively by reducing some of the social disruptions occurring in the two Native communities. However, reduced mercury levels in fish would not address many of the other problems and issues that have affected the two Bands.

Benefits were compared with costs of remedial actions. Financial values of the benefits alone were insufficient to offset the costs of the remedial projects. A monetary value of at least $12.5 million (in present value terms) would have to be attributed to possible reduced health risks and benefits associated with sport fishing (if any) or other amenity benefits in order to justify the cost of the dredging project.

There is substantial uncertainty as to whether the recommended remedial actions will accelerate the decline of mercury in fish. Consequently, realization of any of the biophysical benefits is uncertain. Moreover, even if

mercury levels in fish declined, the monetary values associated with the beneficial consequences would have to amount to $12.5 million in order to economically justify the dredging project. Finally, there do not appear to be any extraordinary social benefits from the dredging project.

The following recommendations are made:

- Given the degree of uncertainty about the biophysical results and their economic values, the dredging proposal should not be implemented at this time.

- Further research in the river systems should focus on the following topics:

  - determining the rate of decline in mercury concentrations in different fish species that would result from sediment removal, covering sediments or resuspension of clean material;

  - obtaining data on sport fishing participation and on tourist service and lodge operations; and

  - surveying Native communities and lodge owners to obtain further information for quantifying and valuing potential benefits.

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CHAPTER 1

INTRODUCTION

1.1 Background

The Wabigoon and English Rivers flow through a series of placid, forest-lined lakes in northwestern Ontario. As shown in Figure 1.1, the Wabigoon begins at Wabigoon Lake near the Town of Dryden. The river flows through the town past the Great Lakes Pulp and Paper Mill (the major employer in the region) and for 85 km (53 miles) through the bush until it widens into Clay Lake. About 150 km (92 miles) downstream from Dryden, the Wabigoon joins the English system at Ball Lake. The English River then flows through a chain of lakes to Tetu Lake where it merges with the Winnipeg River. The Winnipeg River finally empties into the south basin of Eagle Nest Lake in Manitoba.

These river-lake systems stretch across a vast, sparsely populated land of boreal forests, low relief and granitic rock outcroppings. Located on the banks of the English River downstream from Ball Lake and near the confluence of the English and Winnipeg Rivers are the Ojibway communities of Grassy Narrows and White Dog (also called the Islington Band). Scattered throughout the system are tourist lodges and wilderness camps catering to sport fishermen, a few cottages and even fewer non-Indian residents.

Early in 1969, mercury concentrations in fish in the Wabigoon-English and Winnipeg River systems downstream from Dryden were found to be substantially higher than fish found in lakes off the system. Subsequent investigations found that the principal source of this contamination was the Great Lakes paper mill at Dryden and a chlor-alkali plant associated with it (German, 1969; Armstrong and Hamilton, 1973; Troyer, 1977). At the time it was discharging the mercury, the mill was owned by the Reed Paper Co.

Commercial fishing in the contaminated lakes and watercourses was terminated by Provincial authorities in the spring of 1970. As a result, opportunities for gainful employment disappeared for many of the Native people from the two main Reserves in the area, Grassy Narrows and Islington or Whitedog. These people, many of whom had subsisted on a steady diet of contaminated fish from these lakes and rivers, were found to have abnormally high mercury levels in their blood. Finally, there was concern that sport anglers, most of whom were from the U.S., would shun the region because of the mercury. If this happened,

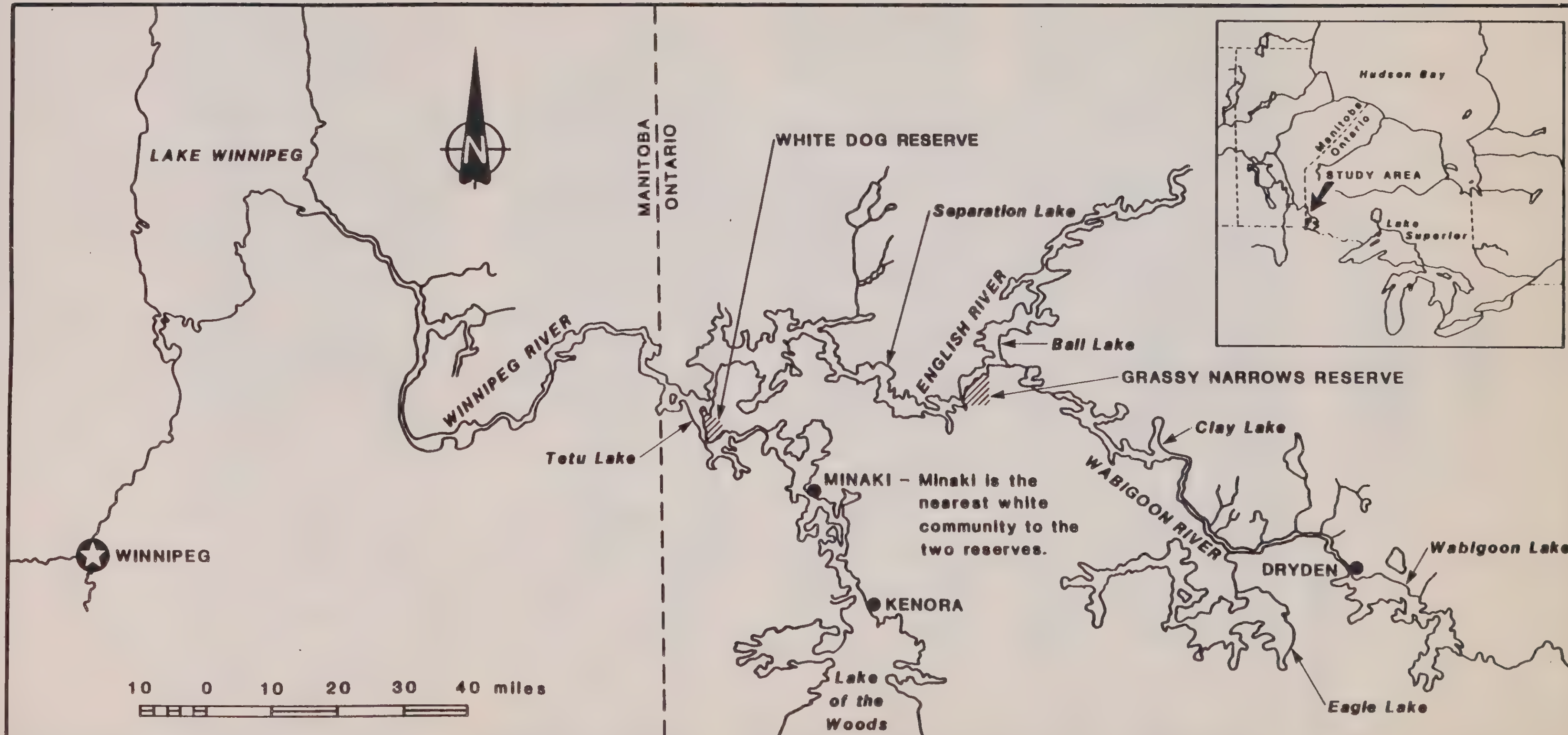


Figure 1.1: Map of the WABIGOON–ENGLISH–WINNIPEG RIVER SYSTEMS in Northwestern Ontario.

fishing camps and lodges in the area could sustain financial losses.

Although mercury levels in fish have declined through natural processes since the curtailment of mercury discharges into the river, desirable sport fish species in the lakes and rivers of the system continue to exhibit mercury concentrations well above the 0.5 ppm limit set by Health and Welfare Canada for fish marketed in Canada, and above the levels found in fish from lakes away from the English-Wabigoon system.

A joint Federal/Provincial study was initiated in 1979 to determine how mercury enters fish and to determine which remedial measures would accelerate the reduction of mercury contamination in fish. The findings of the Federal and Provincial scientists are found in The Technical Report, Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures, (1984). A Steering Committee also produced a Summary of the Technical Report (1983).

The Technical Report consists of three sub-reports: Parks *et al*. (1984), Jackson *et al*. (1984) and Rudd *et al*. (1984). Each sub-report will be referenced separately.

In addition, Acres Consulting Ltd. (1982) completed a study of the technical feasibility and the costs of the two most favoured remedial measures, removal of the contaminated sediments in the Dryden to Clay Lake section of the Wabigoon River and covering contaminated sediments with clean clay or silt.

The primary objective of these remedial measures would be to speed up the reduction of mercury in fish to background levels or to concentrations that would permit unrestricted consumption of fish by those who visit or live in the region.

1.2 Objectives of the Present Study

The proposed remedial programs could cost millions of dollars. Since government resources are limited, it is prudent to determine just what beneficial results could be derived from these efforts. This information would be needed to judge whether the benefits of the remedial measures are commensurate with their costs.

Consequently, the intent of this study is to integrate the available scientific, engineering, social and economic information into a policy-relevant format which shows what the problem is, what the preferred remedial options might cost and what society, as well as specific groups and

individuals, stand to gain or lose under each potential course of action. In addition, the social implications of the rehabilitation efforts are identified, discussed and incorporated into the assessment, where possible.

With this information, informed judgements and choices can be made concerning this and other contentious issues. Moreover, an assessment of this type can sometimes identify other possible approaches to resolving the problems at hand.

This report complements reports by Acres (1982), the Federal/Provincial Technical Report (1984) and the Summary of the Technical Report (1983) on the Wabigoon-English River System, incorporating relevant data and information from these documents and other sources.

1.3 Benefit-Cost Analysis - Strengths and Weaknesses

Benefit-cost analysis has evolved as a method to determine the economic desirability of large, publicly-funded resource development investment projects such as dams and irrigation schemes. It has been extended to a wide variety of public policy issues including environmental protection. A great deal of thought and research has been devoted to the development and refinement of the technique during the past three decades (Hufschmidt *et al*. 1983: 3, 4). In particular, the literature on the application of benefit-cost analyses to pollution control and environmental protection issues has grown substantially in recent years (Desvousges and Smith, April 1983; Hufschmidt *et al*., 1983, Halvarsen and Ruby, 1981).

Nevertheless, many people object to the application of benefit-cost analyses to environmental questions because they regard pollution and its abatement as moral, rather than economic, issues (McAllister, 1982). However, despite the widespread and consistent public support for environmental protection, both public and private agencies are constrained by limited resources. When program choices and budgetary allocations are made, a comparison of benefits and costs invariably takes place, even if it is only implicit. A benefit-cost analysis makes such comparisons explicit. While the technique need not dictate policy choice, it can help generate, clarify and integrate information that government officials and the public need to make informed choices and decisions.

Monetary values based on market prices are used to weight or value resource inputs or the opportunity costs of a project, as well as the potential outputs or benefits.

The transformation of biophysical quantities to monetary equivalents facilitates aggregation and direct comparison of otherwise incommensurate inputs and outputs. Moreover, monetary values based on market prices also serve as indicators of relative worth or importance to society. In this capacity, monetary values have the following strengths and advantages:

- market prices are based on the willingness-to-pay of individuals who are free to choose what they want within the constraints of available income and knowledge;

- because market transactions and market prices are the result of voluntary exchanges, each party (e.g. the consumer and the producer) perceives himself to be somewhat better off. Consequently, increasing market values reflect improving social well-being;

- market prices represent an equilibration of an individual's willingness-to-pay and a producer's willingness-to-sell. Market prices thus constitute the most representative or objective measures of value that are available; and

- monetary values are widely understood, accepted and used as signals for making decisions and choices.

The key question that a benefit-cost analysis seeks to answer is whether or not society as a whole will be better off as a result of the project or program in question. Society will clearly be better off if some people gain while no one loses or, if some people do lose, they are compensated to the extent that they do not perceive themselves to be worse off.

However, all public projects have gainers and losers or, in other words, those who pay for the project with taxes lose something while those who receive the benefits are gainers. In these situations, individual payment is usually so small as to be not worth a taxpayer's while to demand compensation.

Consequently, projects are deemed to be economically feasible if the monetary value of all benefits, to whomsoever they accrue, is sufficient to compensate the monetary value of the inputs or any benefits that are foregone (e.g. opportunity costs) in order to implement the project whether or not compensatory payments are ever made.

Thus, where the inputs (or opportunity costs) and the outputs of a project involve marketed goods and services

with associated price information, indicators can be computed in the course of a benefit-cost analysis to determine whether the project is economically viable. These measures include:

(1) Annualized Net Benefit

First, the annual payment, including interest, to repay the capital cost over a specified number of years is added to the average annual operating and maintenance cost. This annual cost is then subtracted from the annual value of the benefits or revenues. The Annualized Net Benefit is calculated using the following equation:

$$AR - [AC - K(Fi)]$$

where:

AR = Average Annual Revenues
AC = Average Annual Operation and Maintenance (O & M) costs
K = Capital Costs
Fi = Annualization factor given interest rate i.

If the result is positive, accept the project; if negative, reject it.

(2) Net Present Value

Streams of benefits and costs typically vary over the life of a project. In fact, some types of environmental benefits are realized many years after a project has been completed. Under these circumstances, a project that is accepted on the basis of the Annualized Net Benefit analysis may, in fact, yield a net cost if all benefits and costs over the life of the project were compared. The best approach would, therefore, be to add up all capital costs, annual costs and annual revenues that are incurred over the project planning period. Future costs and revenues are discounted to reflect the fact that people value money and income received in the present more than if they were received in the future. The present value of costs is then subtracted from the present value of the benefits to determine the Net Present Value (NPV) of the project. The discount rate is generally based on market interest rates and is intended to represent the opportunity cost of the capital funds that are used for the particular project or program.

The Net Present Value of a project or program is calculated using the following equation:

$$\sum_{n=1}^{T} \frac{(R_n - AC_n - K_n)}{(1 + i)^n} = NPV$$

where:

R_n = revenue in year n
K_n = capital cost in year n
AC_n = O & M cost in year n
i = discount rate
T = duration of project, years

If the resulting NPV is positive, accept the project; if it is negative, reject it.

(3) Asset Value

The asset value is the amount of money that would have to be deposited in a bank at a given interest rate to yield a return equal to the annual value of the net benefit. The asset value is calculated by dividing the annual value of the benefits by the desired rate of return. The prevailing market interest rate can be a point of departure. If the capital cost of the proposed project is larger than the asset value of the expected annual value of benefits, then project funds could be invested elsewhere in order to obtain a higher financial return.

Two other indicators or criteria are often used in benefit-cost analyses to determine whether a particular project is economically viable or to rank a number of different projects or program options:

(1) Benefit-Cost Ratio

The present value of project benefits is divided by the present value of project costs. A ratio of 1.0 or greater indicates that the value of project benefits exceeds the value of project costs so that the project is deemed economically feasible or justified. A ratio of less than 1.0 indicates that the project is not economically feasible.

(2) Internal Rate of Return

This is the discount rate at which the present value of benefits is equal to the present value

of the costs. Consequently, the net present value is zero.

As discussed in Halvarsen and Ruby (1981: 46-52) and Hufschmidt et al. (1983: 40-42), these two indicators obscure the actual magnitude of the benefits and costs and do not always lead to the selection of an option with the highest net present value. Consequently, neither the benefit-cost ratio nor the internal rate of return will be used in this study.

A benefit-cost analysis differs from a cost-effectiveness analysis. Whereas benefits are explicitly measured and valued in a benefit-cost assessment, only the costs of different methods or technologies that will achieve a particular goal, objective or output are determined in a cost-effectiveness analysis. Thus, the most cost-effective option is defined as the one that:

(1) maximizes the output for a fixed cost, or

(2) minimizes the cost of producing a fixed output.

Cost-effectiveness analysis is not applicable to projects or programs which yield different configurations of beneficial outputs or consequences.

When applied to environmental issues, the benefit-cost analysis technique has the following limitations:

(1) many of the beneficial consequences of environmental protection are not bought or sold in markets and do not have market prices, hence monetary values, associated with them. Analyses that focus on monetary values ignore these benefits;

(2) a number of environmental effects and consequences take many years to manifest themselves. Discounting substantially reduces the importance of these future effects, whether they are costs or benefits, in a benefit-cost analysis;

(3) focussing only on the monetary values of net benefits or the Net Present Value obfuscates social issues and bio-physical information that can be relevant to decision-making;

(4) matters such as nuclear radiation and toxic materials can expose whole populations to very subtle influences of which they may be entirely unaware. It is difficult to know what normative value individual preferences have under these circumstances; and

(5) because willingness-to-pay is a primary basis for many monetary value estimates, values are often constrained by the ability to pay or available incomes. Consequently, low income individuals and groups can be selectively discriminated against in a benefits-cost analysis.

The following modifications and extensions to the benefit-cost framework are proposed to overcome some of the above limitations and to enhance the usefulness of the methodology when applied to environmental projects or issues.

1.4 Modifications to the Benefit-cost Framework

1.4.1 Comprehensive Definition of Costs and Benefits

The first modification involves a more comprehensive definition of costs and benefits. A project which produces environmental improvements generates two broad types of costs and benefits:

- **Private costs and Benefits** are incurred or enjoyed by the proponent or agency which initiates the project. Private benefits include increased revenues, cost savings or increased profits that result from the project or investment.

- **Public Costs and Benefits** are adverse or beneficial consequences which are imposed on individuals or firms not connected with the project proponent. Public costs are the environmental damages caused by pollution or development activity. Public benefits are biophysical damages that are avoided, reduced or eliminated as a result of a project or a program. Public benefits also include the tangible and intangible beneficial consequences that result from environmental improvement.

1.4.2 Quantification of Biophysical Consequences versus Valuation

The public benefits associated with environmental protection activities are derived from the biophysical effects and changes that result from the maintenance or improvement of environmental quality. Given appropriate dose-response information, many such effects and consequences can be systematically identified and quantified in appropriate biophysical units. Changes in commercial fish harvests, increases or decreases in illness or mortality, additional sport fishing opportunities, for example, can be quantified to varying degrees.

This information is often useful in its own right, but estimates of biophysical effects cannot be compared directly with the costs of the project or even with each other. The next step is to place values or weights on these consequences as a separate exercise. As indicated, economic or monetary values are employed in this study although other valuation or weighting methods could be applied to the biophysical information provided if so desired.

1.4.3 Valuation of Benefits

The basic principles for assigning monetary values to any tangible and intangible good, service or attribute are as follows:

- if people gain a benefit or receive protection against future damages or losses, the appropriate monetary value is the maximum amount they are willing to pay for the benefit. This measure of value is called **Willingness to Pay** (WTP); and

- if people sustain losses of damages to something for which they perceive to have a right (e.g. health or property), then the most appropriate monetary value is the minimum amount of money they would require in compensation to endure the loss and not feel worse off. This measure is referred to as **Compensation Required** (CR).

It is easy to visualize situations in which these two types of vales would diverge widely, especially since WTP is tempered by an individual's ability to pay. However, in the process of voluntary market exchanges, WTP and CR reduce to a single market price. Where environmental goods, features or attributes are not bought or sold in markets, no market prices are available, so that other methods must be applied to estimate WTP or CR values.

The change in economic welfare that results from changes in environmental quality is measured by the extra money people are willing to pay, over and above the price they actually have to pay (which, in many instances, is zero). This value is called **consumers' surplus.** Consumers' surplus is often manifest in the satisfaction that one feels in buying something for a lower price than is charged elsewhere.

A second important monetary measure of economic welfare is called **producers' surplus** or, more simply, **profit.** This is the difference between the revenues received by a producer and the cost of the inputs used (or the benefits foregone) to produce a good or service. The

sum of changes (increases or decreases) in all consumers' and producers' surpluses represents the increase or decrease in wealth or economic welfare for society as a whole. Estimates of these values are properly compared with the "opportunity costs" (e.g. financial outlays and/or other sacrifices or adverse effects) of the project.

Where environmental effects result in changes in the productivity of marketable resources such as forests, fisheries or crops, market prices are available for valuation. Producers or users thus incur increased or decreased costs or revenues, or **financial values.** For example, changes in health care costs are the financial values associated with human health effects.

People are often willing to pay something to preserve and enjoy environmental resources, features or attributes which are not for sale in a market. Rare plants or animals, unique natural environments, scenic vistas, avoidance of pain and suffering from disease or aesthetics may be valued by people whether or not they actually use these features. Furthermore, if the future availability of a particular environmental feature or attribute is uncertain, individuals have been shown to be willing to pay an amount, over and above the current price, to preserve an option for future use or merely to ensure its continued existence.

Values in excess of financial value estimates are collectively referred to as **amenity values.** They further indicate the potential change in economic welfare that people associate with environmental improvements or degradation. Amenity values refer to those intangible effects, features and consequences which people consider necessary to social, economic and ecological well-being, as well as those which might otherwise be considered luxuries.

Further discussion of these concepts may be found in Maler and Wyzga (1976) and in a report by the Ontario Ministry of the Environment (April 1984).

1.4.4 Discounting Costs and Benefits Over Time

It is generally appropriate to discount costs and benefits in order to reflect the fact that people value income received in the present more than if it is to be received in the future. However, the choice of an appropriate discount rate is the subject of on-going debate and controversy. The higher the discount rate, the lower the present value of future benefits and costs. At any positive discount rate, the present value of a sum incurred more than 50 years in the future is negligible.

Consequently, future generations are systematically discriminated against when discounting is applied.

MacAllister (1980: 270-271) argues that the value of environmental benefits that will be generated in purpetuity and will be enjoyed by future generations should not be discounted. Other authorities suggest that a social discount rate should be significantly lower than current, market-based discount rates.

Consequently, where monetary values can be estimated for benefits in this study, both discounted and undiscounted values will be shown. The rate used in this study is a 10% nominal discount rate as recommended by the Treasury Board of Canada.

1.4.5 Economic Activity Effects

Another type of economic consequence that a comprehensive benefit-cost assessment can reveal is the change in **economic activity** associated with a program or project. This is measured by the increases or decreases in expenditures, income or employment that accompany the project. Estimates of economic activity effects are often important considerations for public programs or policies, but they are generally not used in benefit-cost evaluations because:

- the effects are often local. Increases in expenditure and/or employment in a community or region are usually offset by corresponding decreases in other communities or regions. The net impact on the jurisdiction will, therefore, be neutral; or

- the effects may only be temporary, such as during a construction period.

Nevertheless, information about economic activity impacts can help to show which groups, sectors or locations stand to gain or lose, in terms of economic activity, because of the program or project.

1.4.6 Social Impacts

Monetary valuations and economic activity changes do not always capture the full story. There may be non-economic, social gains or losses that have occurred as the result of the project. In this study, the social consequences of the mercury contamination and the potential effects that the rehabilitation projects might have on the communities and groups affected by the pollution are identified and discussed.

The distribution of the various costs and benefits of different rehabilitation options among specific groups and regions will also be specified. This will provide another dimension to the social consequences of the proposed project.

1.4.7 Dealing With Uncertainty

Ecological interrelationships are complex and not well understood. Consequently, there often is considerable uncertainty about the effects pollutants may have on ecosystems and about the consequences of pollution control and environmental protection efforts. This means that the beneficial results of pollution control or rehabilitation programs cannot always be predicted with the degree of certainty that is desired for policy deliberations. Fortunately, there are systematic methods which can be applied when consequences are uncertain.

One approach is to prescribe a possible range for relevant dose-response relationships or other effects. One can conduct "sensitivity analyses" using different values in the dose-response formulations to determine which variables would have the most significant effect.

Another approach is to determine statistical (e.g. based on observed experience) or judgemental (e.g. based on the opinion of experts) probabilities for each of the various possible effects and consequences. Multiplication of these probabilities by the biophysical consequences or the appropriate monetary values yields an Expected Value of the consequence in question. Where the probabilities are less than 100%, Expected Values of the likely results will necessarily be diminished.

Finally, the application of a "decision-tree" analysis as described by Keeney *et al*. (December 1981) and North and Balson (1985) can highlight the likelihood and the Expected Values associated with each potential course of action.

These methods for dealing with uncertainty will be applied in the present study to the extent possible.

CHAPTER 2

MERCURY POLLUTION ON THE WABIGOON, ENGLISH AND WINNIPEG RIVER SYSTEMS - EFFECTS AND DAMAGES

2.1 Patterns of Contamination and Identification of Effects

From 1962 to October 1970, between nine and eleven metric tonnes of mercury were discharged into the Wabigoon River at Dryden, Ontario from a mercury cell chlor-alkali separation process used at the paper mill (Parks *et al.*, 1984 Ch. 2 and Ch. 7). These discharges resulted in elevated mercury levels in the water, sediments and fish in the river system. During most of the period when mercury was discharged into the river, the mill was owned by Reed Paper Co., a British-based company. The mill was purchased from Reed in 1981 by Great Lakes Paper (now Great Lakes Forest Products), a subsidiary of Canadian Pacific Investments.

Mercury is a metal which is liquid at normal temperatures. Mercury is toxic to humans if sufficient quantities are ingested or if the fumes are inhaled. However, mercury can be chemically combined with organic molecules to form ethyl or methylmercury which substantially increases the toxicity of the metal.

Spurred by methylmercury poisoning tragedies in Minimata, Japan and elsewhere and by the discovery of high levels of mercury in fish and wildlife in Scandinavia and Manitoba, Provincial and Federal authorities launched a major fish testing program in Ontario in 1968. The results of the testing program, along with the results of tests done by independent researchers, revealed high mercury concentrations in fish from a number of locations, especially in the Wabigoon-English River System and in Lake St. Clair. Commercial fishing was banned by the Provincial Government in these waters in the spring of 1970. Sport fishing on the English-Wabigoon was not banned, although in 1970, Provincial authorities posted warnings against eating fish throughout the region. (Consumption guidelines are also issued in the report, "Guide to Eating Ontario Sport Fish", published annually by the Ministries of the Environment and Natural Resources).

Mercury losses from the Dryden chlor-alkali plant were curtailed in the fall of 1970, although significant discharges continued until November 1975 when the mercury-cell chlor-alkali separation process was dismantled and replaced. The total complex still discharges about 4 kg of mercury per year, which is derived from naturally

occurring mercury in the trees (Parks et al., 1984:322). Most of this mercury ultimately escapes into the atmosphere via biochemical processes (Parks et al. 1984, Ch. 4: 124).

Parks et al. (1984, Ch. 3) found inorganic and organic forms of mercury in the sediments of the lakes and streams below Dryden and in the water column. Mercury in the sediments is the residue of the mercury that had been previously discharged from the mill at Dryden rather than "new" mercury that is currently being discharged into the river system.

Concentrations of mercury in water and fish are expressed in a confusing variety of units. Concentrations in water are measured as micrograms per litre (ug/L). This is equal to 1 part mercury in 1 billion parts water or parts-per-billion (ppb). Mercury in sediments and fish flesh is expressed as micrograms per gram (ug/g). This is equivalent to 1 part mercury in 1 million parts fish (ppm). Mercury is sometimes present in such small amounts that it is expressed in nanograms per litre or gram (ng/L or ng/g). A nanogram is 1/1000 of a microgram, or one billionth of a gram and one trillionth of a litre.

When metallic mercury enters the river system, it is transported downstream and, over time, translocates from the water to sediments and into food chains. Some of the mercury is ultimately lost to the atmosphere and some is transformed into methylmercury which is also taken up in food chains.

Mercury concentrations in the sediments of the Wabigoon River near Dryden average 10-15 ug/g (ppm), well above background values of 0.01 to 0.1 ppm in sediments uncontaminated by industrial inputs. According to Parks et al. (1984, Ch. 3), between 4,300 and 7,000 kg of residual mercury still remain in the sediments from Dryden to the outlet of Clay Lake. These residues are the principal source of mercury to the water and to fish through mechanisms described by Reeder, Demayo and Taylor (1979: 3-4).

During 1980, mercury concentrations in the effluent from the Great Lakes Forest Products mill averaged about 194 micrograms per litre (Parks et al., 1984: 324). This is equal to 194 ppb or .194 ppm. Mercury concentrations in the waters of the Wabigoon-English System decline with distance from the mill. In the Wabigoon River itself, concentrations range between 24 and 29 ng/L. Downstream, in the English River, concentrations average 5 to 8 ng/L which is close to the 3-5 ng/L values found in uncontaminated waters (Parks et al., 1984: Ch. 4). The Department of Health and Welfare Canada has recommended a limit of 1,000 ng/L or 1 ppb of total mercury in drinking water (Reeder et al., 1979: 4). Consequently, the levels of mercury in the waters of the Wabigoon and English Rivers

are substantially below the drinking water criterion recommended by Health and Welfare Canada.

Mercury enters fish from water passing over their gills and from food. Carnivorous fish such as northern pike (Esox lucius) and walleyed pike or pickerel (Stizostedion vitreum) derive 50% of their methylmercury body burden from contaminated food and 50% from water. Carnivorous fish tend to accumulate heavy body burdens of mercury whereas non-carnivorous species, such as whitefish (Coregonus clupeaformis), do not. Because carnivorous fish are the the most desirable sport and commercial species, walleyes and northern pike are used as the primary indicator species for monitoring mercury levels.

Mercury concentrations in northern pike taken from lakes unaffected by industrial wastewater discharges range from .4 to 1.4 ppm (Bishop and Neary, 1976). While about 75% of the fish tested were below the 1 ppm level, only about 10% were below the .5 ppm limit for the sale of commercially caught fish. Figures 2.1 and 2.2 illustrate the concentration of mercury in various sized pike and walleye taken from different parts of the river-lake system. Concentrations in walleyes and northern pike are clearly above 1 ppm in Clay, Separation and Ball Lakes.

Mercury concentrations in whitefish, which make up a large part of commercial catches, average .8 to 1 ppm on the Wabigoon-English system, as compared to levels of .2 to .3 ppm in lakes away from the System.

While mercury does not appear to harm the fish, it does pose a health threat to people who eat them. Since average mercury concentrations in game fish vary in proportion to their size, guidelines for fish consumption have been developed by the Ontario Government which relate to these factors. Figure 2.3 shows the 1983 sport fish consumption guidelines for various lakes in the Wabigoon-English System. Fish consumption guidelines clearly become less restrictive downstream from Dryden. Prior to 1983, none of the fish in Clay Lake and very few of the fish in Ball Lake could be eaten.

While mercury levels in fish decline downstream from Dryden, contamination levels in fish have been declining over time as well. This trend is illustrated in Figures 2.4 and 2.5 which show mean concentrations for northern pike and walleyes in three lakes from 1970 to 1982. This natural decline was the expected result of curtailing mercury discharges in 1970. However, the mean concentrations in both walleye and pike found in the lakes of the system still have concentrations above 1 ppm. Studies of mercury in young fish suggest that the rate of decline of mercury concentrations in pike and walleye may be slower in the future than has occurred in the past (Canada-Ontario Steering Committee, 1983: 10-11).

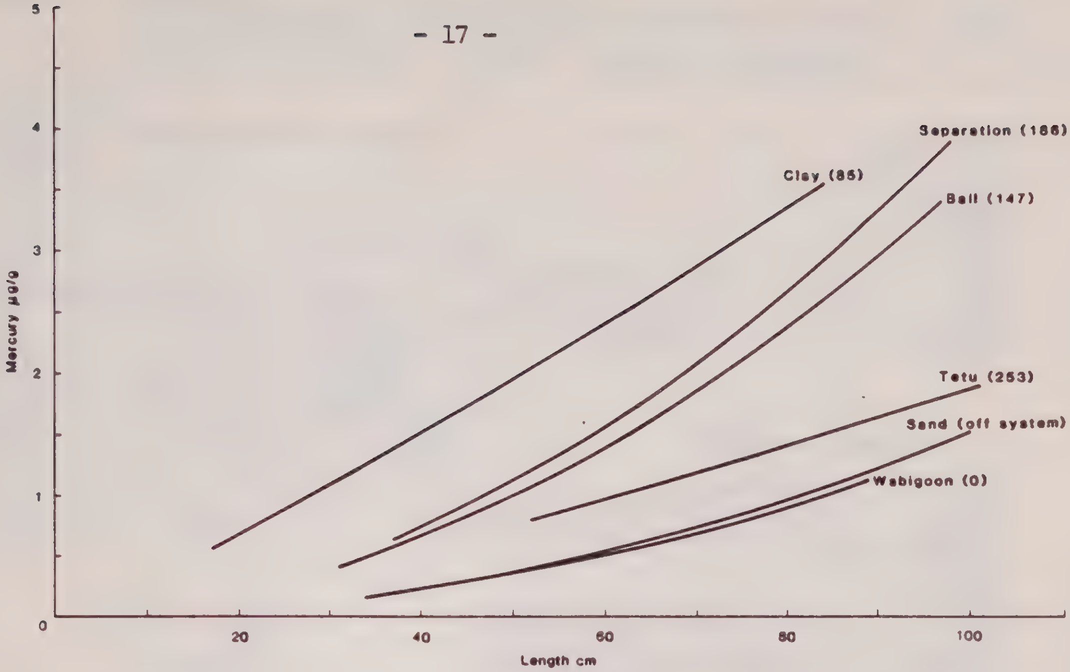


Figure 2.1: Mercury concentrations in adult Northern Pike from seven lakes in the Wabigoon/English/Winnipeg River system, 1982. Numbers in (85) represent kilometers from Dryden. (Parks <u>et</u> <u>al</u>. 1983, Fig. 5.12).

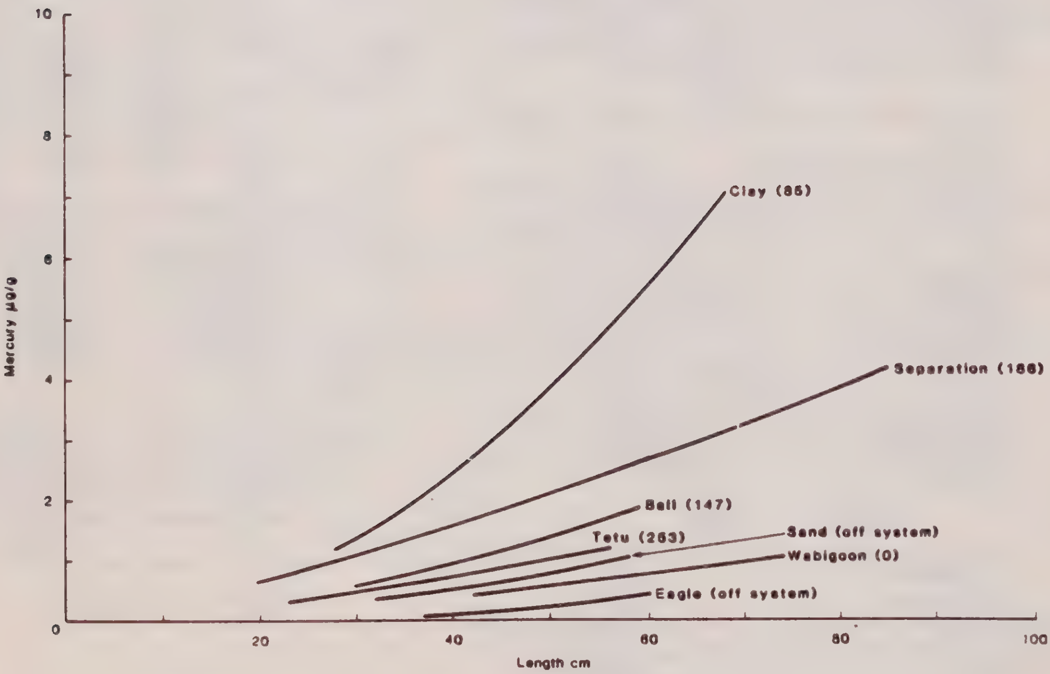
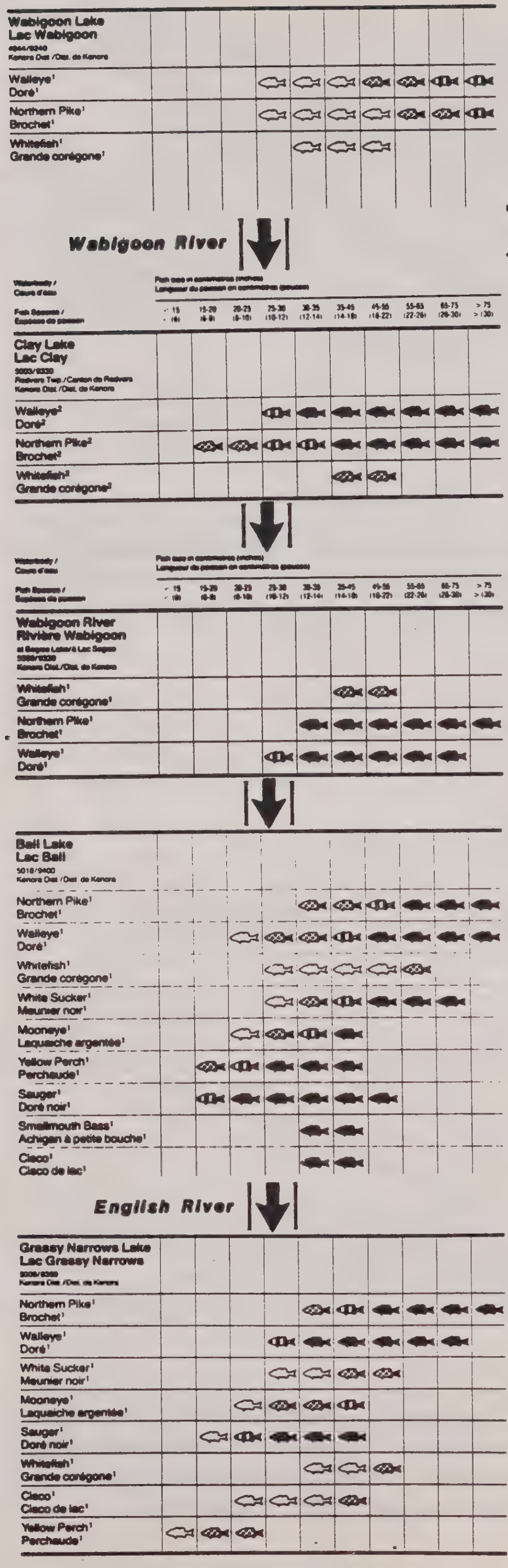


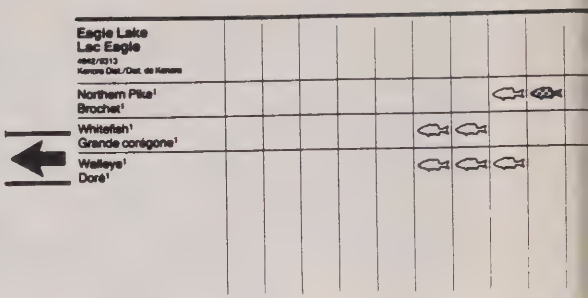
Figure 2.2: Mercury concentrations in adult Walleye from seven lakes in the Wabigoon/English/Winnipeg River system, 1982. Numbers in (85) represent kilometers from Dryden. (Parks <u>et</u> <u>al</u>. 1983, Fig.5.11).

Figure 2.3: Fish Consumption Guidelines for Various Lakes in the Wabigoon - English - Winnipeg River Systems, 1982.

Lakes which are in direct sequence below Dryden.



Lakes which are tributary to the system.



Key to Symbols

Consumption Guidelines					
One week	No restrictions	10 meals per wk. 2.3 kg./wk. (5.1 lb./wk.)	7 meals per wk. 1.54 kg./wk. (3.4 lb./wk.)	1 or 2 meals/wk. 0.45 kg./wk. (1 lb./wk.)	None
Two weeks	No restrictions	5 meals per wk. 1.3 kg./wk. (2.8 lb./wk.)	4 meals per wk. 0.86 kg./wk. (1.9 lb./wk.)	1 or 2 meals/wk. 0.45 kg./wk. (1 lb./wk.)	None
Three weeks	No restrictions	4 meals per wk. 0.95 kg./wk. (2.1 lb./wk.)	3 meals per wk. 0.63 kg./wk. (1.4 lb./wk.)	1 or 2 meals/wk. 0.45 kg./wk. (1 lb./wk.)	None
Long-term consumption	No restrictions	0.226 kg./wk. (0.5 lb./wk.)	0.136 kg./wk. (0.3 lb./wk.)	1 or 2 meals per month 0.45 kg./mo. (1 lb./mo.)	None

Contaminant identification		Identification des polluants
1	Mercury	Mercure
2	Mercury, PCB, mirex and pesticides	Mercure, PCB, mirex et pesticides
3	PCB, mirex and pesticides	PCB, mirex et pesticides
4	Mercury, PCB and mirex	Mercure, PCB et mirex
5	Mercury, other metals, PCB, mirex and pesticides.	Mercure, autres métaux, PCB, mirex et pesticides
6	Mercury, other metals.	Mercure et autres métaux
7	2,3,7,8-TCDD (Dioxin)	2,3,7,8-TCDD (dioxine)
8	Toxaphene	Toxaphène

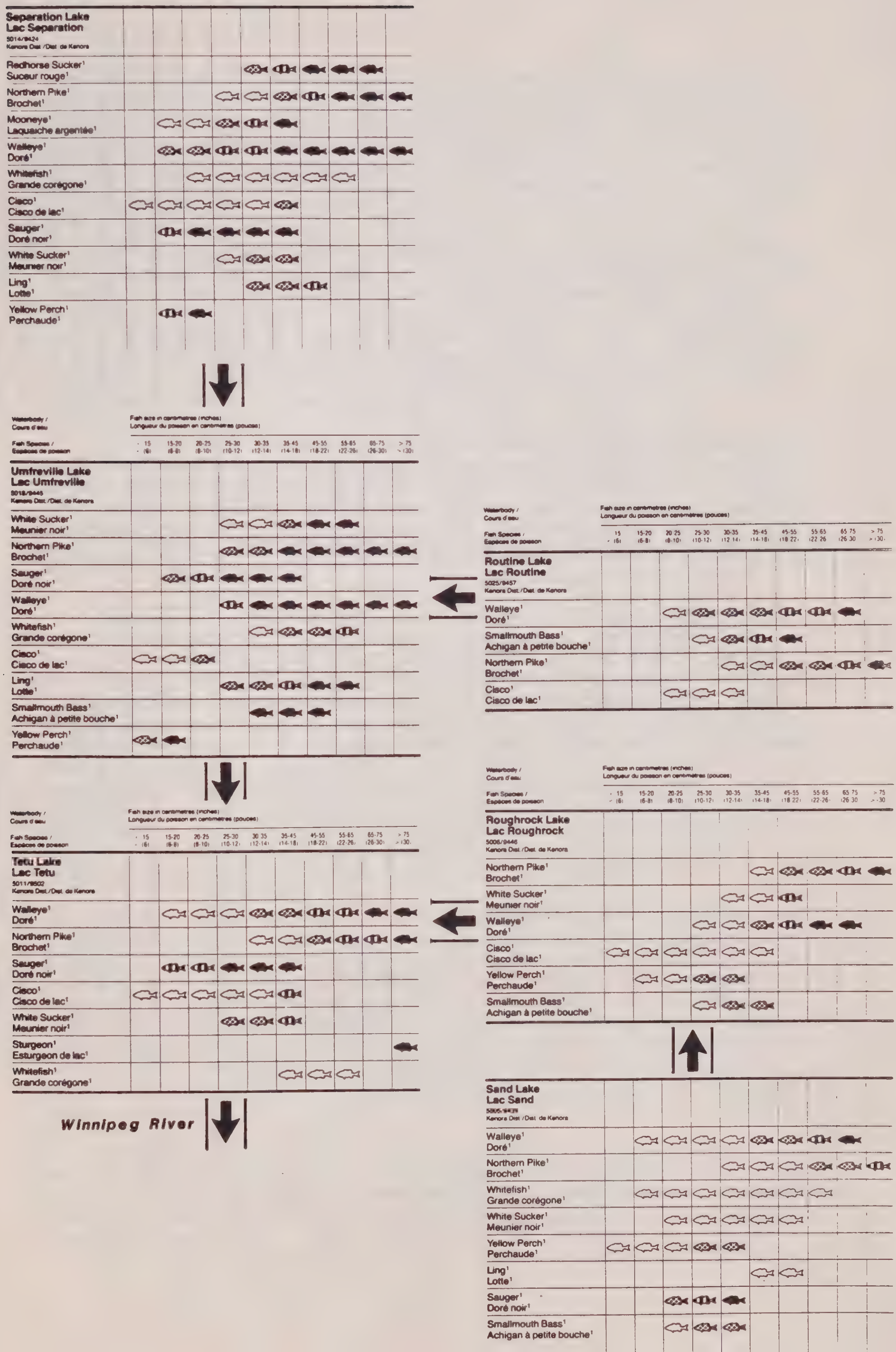
Source: Ontario Ministry of the Environment, Guide to Eating Ontario Sport Fish, Northern Ontario, Lake Huron, Lake Superior, 1983.

continued

Figure 2.3: continued

Lakes which are in direct sequence below Dryden.

Lakes which are tributary to the system.



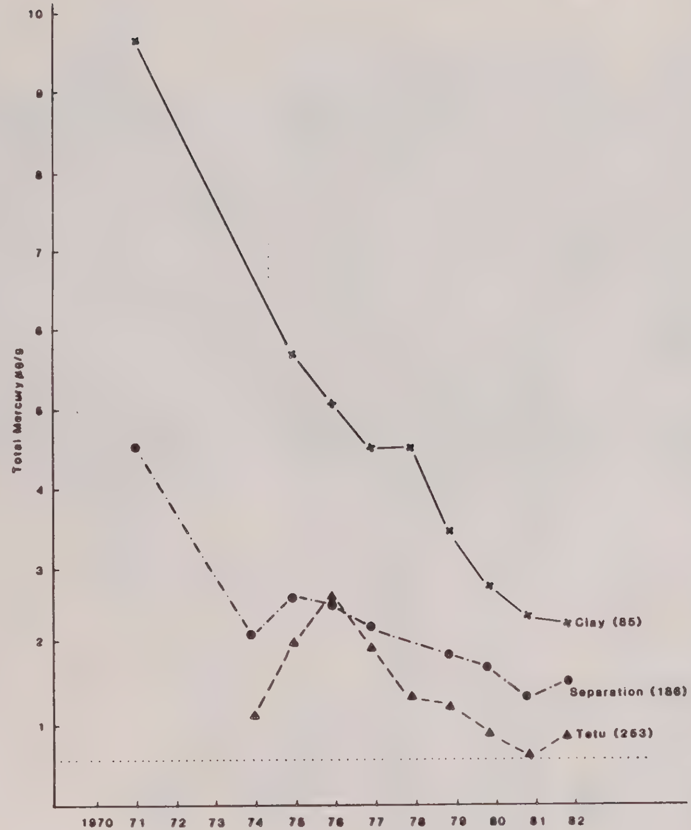


Figure 2.4 : Mercury concentrations in 60 cm Northern Pike from three lakes in the Wabigoon/English/Winnipeg River system, 1971-82. Dotted line represents mean of four, on-system control sites. Numbers in (85) represent kilometers from Dryden. (Bishop and Neary, 1976).

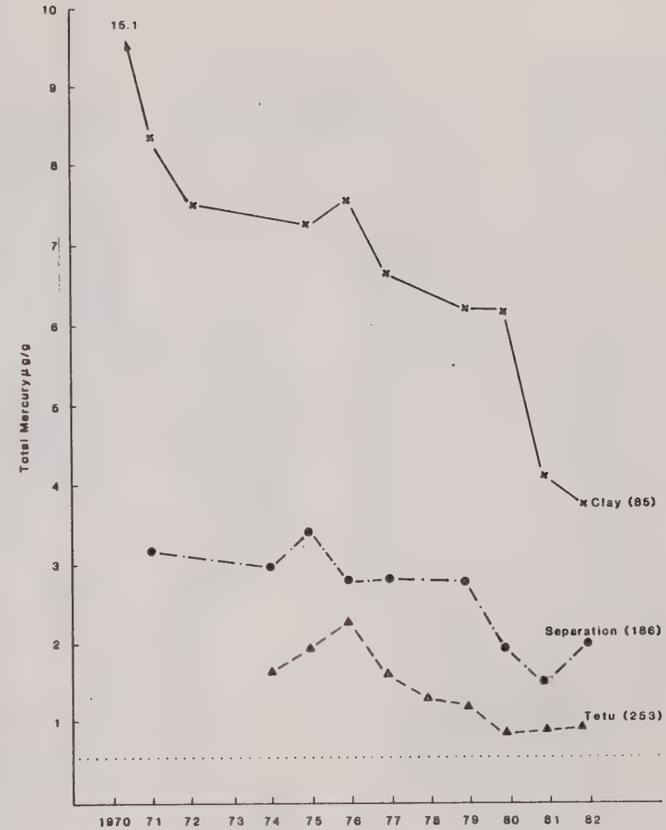


Figure 2.5 : Mercury concentrations in 50 cm Walleye from three lakes in the Wabigoon/English/Winnipeg River system, 1970-82. Dotted line represents mean for four, on-system control lakes. Numbers in (85) represent kilometers from Dryden. (Parks _et al_. 1983, Fig. 5.19).

The link to people is the contamination of fish and the main source of the benefit of any remedial action is the acceleration of the decline of mercury concentrations in fish. Consequently, it is necessary to estimate the extent to which the proposed remedial actions will actually reduce mercury concentrations in fish faster than would occur naturally.

Parks et al. (1984, Appendix 8), developed a model to estimate the changes in mercury concentrations in northern pike at the inflow to Clay Lake at different loadings of mercury. Application of this model suggests that if industrial loadings of mercury were reduced by 2 - 5 kg per year, indicator fish in Clay Lake would reach 0.5 ppm in 60-70 years through natural processes without remedial actions (Parks et al., 1984, p. 350).

In addition to this work, the Ministry of the Environment commissioned Mackay and Paterson (1982) to develop a model to predict changes in mercury concentrations under different amelioration scenarios. Mackay and Paterson provide the only estimates of the decline in mercury concentrations in fish that might result from different remedial measures.

Based on the Mackay and Paterson "fugacity" model, mercury levels in pike from Clay Lake are predicted to decline by 50% in 16 years and by 65% in 32 years (Mackay and Paterson, 1982: Fig. 5.16). The model further predicts that mercury concentrations in pike in two other lakes, Separation and Umfreville, would not change because of the massive dilution by the English River. The authors stress that the trends indicated by the results of the model are more accurate than the absolute predicted values. They note that concentrations and timing of declines are subject to an error of 1.5, or 50%, in either direction (Mackay and Paterson 1982: 19). This implies that a 50% reduction in mercury levels could take as long as 24 years.

Both Parks et al. (1984: 344-345) and Mackay and Paterson (1982) stress the limitations of their respective models. Consequently, their results and estimates are subject to an unknown degree of error or variation. However, neither study provides estimates of either the variance or the probabilities associated with their results. Ranges of these results cannot, therefore, be determined. Nevertheless, they constitute the only systematic estimates of the possible changes resulting from remedial actions.

While the key link of the mercury contamination to people and to human uses is through the contamination of fish, the chief effect, and one that engenders the most concern, is the human health risk derived from eating contaminated fish. This risk can be avoided by limiting the uses that can be made of the fish. Commercial fishing

was, therefore, curtailed to prevent contaminated fish from reaching markets and imposing a health risk on consumers.

Mercury contamination may also reduce the satisfaction and enjoyment felt by sport fishermen. Even non-fishermen might suffer displeasure at knowing that fish are contaminated. Finally, social and economic disruptions can result from these effects and from the government responses to the problem. Before these effects and disruptions are described in subsequent sections, the resources and users at risk from mercury contamination must be identified and enumerated.

2.2 Resources and Users at Risk

2.2.1 Contaminated Lakes

Ten lakes comprise the Wabigoon-English System downstream from Dryden, Ontario to the Manitoba border. In addition, there are at least 8 other lakes that are connected to the system into which fish may swim freely. The extent of mercury contamination in these lakes is shown in Figure 2.6 which also shows the approximate location of the camps, lodges and communities on the system.

2.2.2 Native Communities

The two Indian settlements are the Grassy Narrows Reserve #21 with a population of 624 and the Islington or Whitedog Band #29 with a population of 827 (Department of Indian Affairs, 1981).

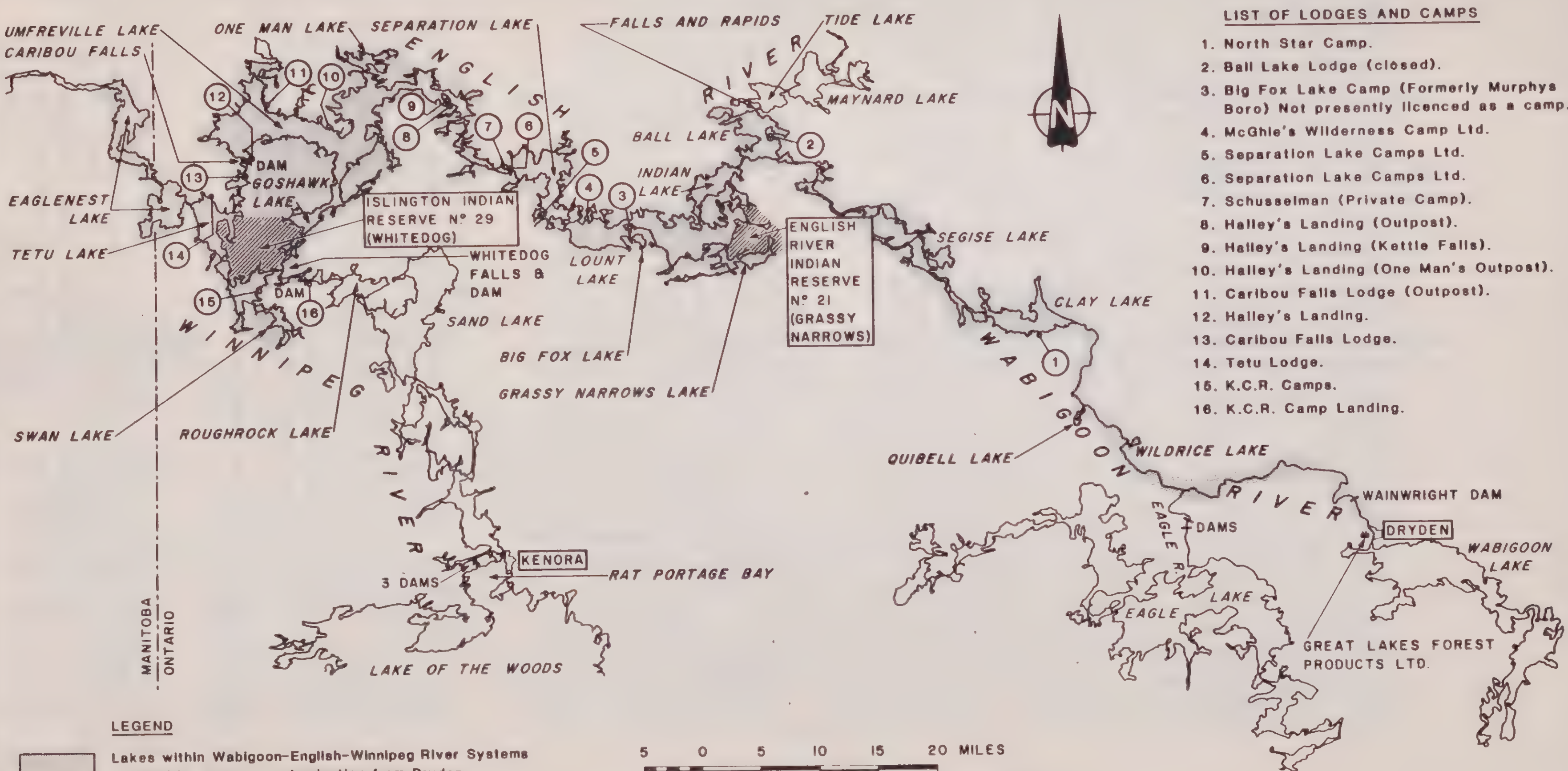
Subsistence fishing has long been an important component of the Native people's lifestyle in this region. Many Native people fished commercially and, prior to an awareness of the mercury pollution, regularly caught fish for home or subsistence consumption.

2.2.3 Commercial Fishing

Native people in the area are currently licensed by the Ontario Ministry of Natural Resources (MNR) to take fish commercially. The Grassy Narrows and the Whitedog Bands, as well as individuals from these settlements, have commercial fishing licenses.

In 1981, the Ontario Ministry of Natural Resources issued 12 commercial fishing licenses or permits to Native Bands and individuals to fish the lakes in the Wabigoon-English System. Another three licenses and two "personal use permits" have been issued to individuals to fish the Ontario portion of the Winnipeg River (MNR, March 1982). Data do not exist on the actual number of people

Figure 2.6: Extent of mercury contamination on the WABIGOON-ENGLISH-WINNIPEG RIVER SYSTEMS and the fishing lodges located in the area.



LEGEND

Lakes within Wabigoon-English-Winnipeg River Systems affected by mercury contamination from Dryden.

5 0 5 10 15 20 MILES

10 0 10 20 30 KILOMETRES

Source: M.N.R. – Kenora District F.&W. Aug.,1982.

employed in fishing under these licenses. According to the Ministry of Natural Resources, each "Band licence" involves at least one family group, which could include up to four people. Based on 1981 license information, employment could total 48 people. These licenses and permits carry with them quotas of 24,490 kg of whitefish per year (Ontario Ministry of Natural Resources, 1982). Because of the mercury contamination, quotas for walleyes and northern pike have not yet been allocated.

As shown in Table A.1, Appendix A, prior to 1970, when the commercial fishing ban was put into effect, an average of 47,000 kg of fish were harvested each year by commercial fishermen from nine of the lakes in the system and from the Winnipeg River. Annual harvests fluctuated significantly.

Commercial fishing in the banned lakes was resumed in 1978-79 for species with mercury levels below 1 ppm. Table A.2 shows that during the years 1978-1981, commercial fishing was resumed with some restrictions on all of the lakes and total harvests averaged 18,134 kg per year. Catches could, however, be expected to vary from 10,000 to 27,000 kg per year.

Comparison of the pre-1970 and post-1978 average annual catches in Table A.4 indicates a decline in total average commercial fish harvest by almost 29,000 kg per year. Average annual walleye harvest for the period 1978-81 was down by almost 12,000 kg to less than 1,000 kg per year. On the other hand, while the average annual whitefish catch during 1978-81 was about 1,000 kg lower than pre-1970 levels, or 11,700 kg, the variation in catch (5,500 kg) during the period 1978-81 was such that the whitefish harvest from these lakes could still exceed the pre-1970 average of 13,000 kg/yr.

2.2.4 Sport Fishing

Sport fishing is a major attraction in Northwestern Ontario for visitors from other parts of Canada and the U.S. Ruston/Shanahan and Associates Ltd. et al. (January 1979) report that 79% of the U.S. visitors surveyed gave sport angling as the principal reason for coming to the area. There are at least nine camps and lodges located on the lakes in the Wabigoon-English System which depend on sport fishing enthusiasts. These camps and lodges are listed in Table 2.1. Men from the Grassy Narrows and Whitedog Bands have served as fishing guides at these camps and lodges.

All but one of the nine recreational service facilities are currently operating and have a combined capacity of approximately 480 overnight guests (W.R. McRae and MNR District Office, 1982, Personal Communications). Ball Lake Lodge, the largest, was closed in 1970 amid public furor over mercury contamination (Troyer, 1977).

TABLE 2.1

RESOURCES AT RISK ON THE WABIGOON-ENGLISH AND WINNIPEG RIVER SYSTEMS BETWEEN WABIGOON LAKE AND THE MANITOBA BORDER

River/Lake	Distance[1] from Dryden (km)	Elevation Above Sea Level (feet)	Settlements	Fishing Camps (visitor capacity per night)	Access Points	Comments
WABIGOON RIVER						
Wabigoon Lake (Dryden)	0	1,210	Dryden	-	road access	Dinorwic Lake upstream, same elevation Gullwing Creek and Eagle River (from Eagle Lake) join dowstream
Clay Lake	85	1,098	-	North Star Camps (65)	road access	-
Segise Lake	110	- " - approx.	-	-	two road access points between Segise and Ball Lakes	-
Ball Lake (confluence of Wabigoon & English Rivers)	147	1,045		Ball Lake Lodge (100) closed 1971		Tide and Dumpy Lakes connected with Ball Lake, same elevation
ENGLISH RIVER						
Indian Lake	154	"	-	-	-	-
Grassy Narrows Lake	161	"	Grassy Narrows Indian Reserve	Grassy Lodge (26)	road access	-
Little Fox Lake	167	"	-	-	-	-
Big Fox Lake	170	"	-	Big Fox Lake Camp	-	Shoe Lake connected with Big Fox Lake, same elevation
Lount Lake	177	"	-	McGhie's Outpost (11)	-	-
Separation Lake	186	"	-	Separation Lake Camps (54) and Wilderness Outpost (8)	-	-

cont'd ... 2

Table 2.1 (cont'd)

River/Lake	Distance[1] from Dryden (km)	Elevation Above Sea Level (feet)	Settlements	Fishing Camps (visitor capacity per night)	Access Points	Comments
Umfreville Lake	222	1,045	-	Halley's Landing and Outposts (104)	road access	One Man and Routine Lakes connected with Umfreville Lake same elevation
Goshawk Lake	251	"	Whitedog (Islington) Indian Reserve	-	road access	-
Tetu Lake (confluence of English and Winnipeg Rivers)	253	984		Caribou Falls Lodge (42)	road access	Upstream from Tetu Lake
				Tetu Lodge (65)		Swan Lake is upstream on Winnipeg River at 989' level
					road access at Roughrock Lake and at Whitedog Falls	Roughrock, Sand, Gun and Pistol Lakes and further upstream on Winnipeg system at 1,024' level. Not affected by mercury contamination.
WINNIPEG RIVER						
Eaglenest Lake	260	"	-	-	-	On Ontario-Manitoba border

[1] Distances have been calculated from mouth of lake to mouth of next lake. Total distance measured is 260 km from Dryden to the mouth of Eaglenest Lake. Based on Ontario, Ministry of Natural Resources, Districts of Rainy River, Kenora and part of Kenora Patricia Portion Map 24-6 (1:600:000)

Sources: Canada, Department of Energy, Mines and Resources, Topographic Maps 52F, 52K, 52L
Ontario, Ministry of Natural Resources, Kenora District, Access Points outlined on a map
Ontario, Ministry of Tourism and Recreation, Kenora Office, List of Fishing Camp and Lodges with visitor capacity.

It is not known whether the closure of Ball Lake Lodge was due solely to the mercury pollution since most of the other establishments remained open. The owners of Separation Lake Camp also closed their establishment claiming that the adverse publicity from the mercury pollution resulted in cancellations and reduced business. However, the camp was purchased by two Kenora businessmen and reopened in 1978 (W.R. McRae, 1982).

Based on an overall occupancy rate of 68%, the camps and lodges in the system currently accommodate about 35,000 overnight visits during each 16-week season.

Angling includes the "fishing experience", as well as the fish caught. Thus, sport fishing is generally measured in angler-hours or angler-days. However, there are no current or historical data on the angler-days of recreational fishing for the Wabigoon-English River System. The only monetary measure of sport fishing activity on the system is gross expenditure, which underestimates the value of fishing since it does not capture the amenity or satisfaction value to anglers. According to W.R. McRae (1982) of the Ministry of Industry and Tourism in Kenora, seven of the operating lodges and camps generate a combined gross annual revenue of $1.5 million, derived primarily from visitors from outside the region.

Mr. McRae was also of the opinion that mercury in fish has had little effect on sports fishing participation in the Wabigoon, English and Winnipeg River Systems in recent years. Furthermore, there is no evidence that a reduction in mercury levels in fish would necessarily draw more anglers to the region.

2.3 Health Risks

The effect of mercury contamination in fish that causes the greatest concern is the health risk to people who eat the fish. The groups potentially at risk are:

(1) Native people at the Grassy Narrows and White Dog settlements;
(2) Sport fishermen;
(3) People who would eat commercially caught fish; and
(4) Other residents who eat fish.

The Federal fish testing program and the bans on commercial fishing for contaminated species have effectively eliminated the increases in risk to those who eat commercially caught fish. The risk to sport fishermen is presumably reduced by the distribution of the Guide to Eating Ontario Sport Fish (Ontario, annual). Of the 58,000

people who reside in the District of Kenora, only the 1,400 Native people who live in the Grassy Narrows and the Whitedog Indian Settlements have ingested enough mercury contamination to suffer possible health effects (Health and Welfare Canada, December 1979). As a result, Health and Welfare Canada (December 1979: 60) recommends that mercury concentrations in fish should be 0.2 ppm or lower before the people at Grassy Narrows and Whitedog communities can safely eat unlimited quantities of fish.

An annual testing program at Native Reserves and settlements by the Federal and Provincial Departments of Health has found individuals with blood mercury levels about 100 ppb (parts-per-billion) (Health and Welfare Canada, 1979).

> "Of 105 individuals in Ontario who have (blood mercury) levels greater than 100 ppb, 98 (93%) were from the two communities of Whitedog (Islington) and Grassy Narrows, with 39 individuals (37%) from Whitedog and 59 individuals (56%) from Grassy Narrows" (Health and Welfare Canada, December 1979: 71).

By the end of 1978, 40 individuals from the Grassy Narrows and White Dog settlements had been clinically examined by a neurologist. Twenty-five had no abnormalities, five had neurological abnormalities stated by the neurologist as "not being due to methylmercury", and 10 had neurological abnormalities which "could conceivably be due to methylmercury" (Health and Welfare Canada, 1979: 72).

While severe methylmercury poisoning, known as "Minimata Disease", has not been confirmed in any of the communities that were exposed to mercury contamination, the people on the Whitedog and Grassy Narrows Reserves are at risk because some people from these communities have blood levels above 100 ppb. High blood mercury levels contribute to anxiety and possibly to specific illnesses or symptoms which these people have exhibited.

Because sport fishing has remained open after commercial fishery was banned, some people on the settlements may have been confused about government warnings and continued to eat contaminated fish from the system. Physical and mental health effects such as anxiety due to mercury contamination in the Wabigoon-English River System have been borne almost entirely by the Native people of the Grassy Narrows and Whitedog Bands.

2.4 Responses to the Pollution

As indicated, Provincial and Federal governments responded to the discovery of mercury contamination in a variety of ways. Commercial fishing was banned. Warnings about eating the fish were posted throughout the system and the annual Guide to Eating Ontario Sport Fish was initiated. A $300,000 cooperative Provincial and Federal scientific study to determine how best to rehabilitate the river system and the contaminated fish populations was also launched. A blood and hair testing program for the Indian Reserves is carried out annually by the Federal Government.

In 1975, freezers were installed on the Grassy Narrows and Whitedog reserves and non-contaminated fish were shipped in by the Ontario Government for free distribution. This program now costs over $35,000 per year for the fish and the maintenance of freezers (McGregor, 1982).

For three years after the commercial fishing ban in 1970, compensation payments were made to the license holders. "Forgiveable" loans totalled $28,425, $22,643 and $12,234 in 1970, 1971 and 1972 respectively (Kenora District Fisheries Management Plan, 1982).

In 1978, a three-year program, "The English- Wabigoon Economic Development Project", was initiated by the Ontario Ministry of Northern Affairs in response to the economic and social hardships and chronic unemployment suffered by members of the Whitedog and Grassy Narrows Bands (Hambly, 1980). This program consisted of a number of programs including wild rice harvesting, a subsidy to the tourist lodges in the region to hire Native people, a shore lunch site maintenance program and a tourist industry training program for Native people. These programs received $70,000 in 1978-79 and $95,000 in 1979-80 (Hambly, 1980).

Most of the Ministry of Northern Affairs' programs have been terminated. This ministry planned to spend only about $11,000 during fiscal 1981-82 in assistance programs for the Wabigoon-English region (Ontario Ministry of Northern Affairs, 1982). A subsidy of approximately $10,000 was provided to commercial fishermen in the fiscal year 1982-83. Contaminated fish were purchased from fishermen and resold where possible. One customer for such fish was a mink rancher in Manitoba. This program has also been discontinued.

The Federal Department of Indian and Northern Affairs has also initiated projects in these communities.

Finally, negotiations to obtain compensation for the Whitedog and Grassy Narrows communities have been carried

out among representatives of the two bands, the Provincial Government, the Federal Government and the present and former owners of the mill at Dryden, Great Lakes Paper and Reed Paper Ltd. Justice Emmett Hall was a key mediator for these negotiations. A settlement was reached in December 1985 which is described in Appendix C.

2.5 Social Disruptions

The discovery of mercury contamination in fish has been the most recent of several disruptive influences to social integrity and self-sufficiency of the Whitedog and Grassy Narrows communities. For Grassy Narrows in particular, the mercury pollution has probably been the most devastating set-back. These disruptive influences and their consequences are chronicled by Troyer (1977), Ward (1983) and Speirs (1983), as well as in a series of programs on CBC Radio called "Under Attack: In Grassy Narrows" (Ideas, 1983).

Prior to 1970, when the mercury pollution was discovered, the Native people in the two communities experienced a steady erosion of their traditional hunting and fishing resources and rights. Hydro electric dams on the English and Winnipeg Rivers had flooded hunting and trapping lands. Competition from non-Native sport hunters and anglers had increased steadily and the Provincial Government gradually extended restrictive hunting and fishing regulations to the Native people. Traditional food gathering activities had been severely curtailed in many areas.

In 1963, the Federal Government relocated the Grassy Narrows band so as to facilitate the provision of schools, medical care, electricity and other social services. According to the Ideas program, the land to which they were moved would not support vegetable gardens as the old site had and the layout of the new settlement was contrary to traditional Native patterns.

Because food producing opportunities were severely limited, the people became heavily dependent on the government for their basic needs. The nutritional value of their diet deteriorated and they were deprived of the opportunity to practice traditional lifestyle activities (Ideas, 1983: 15-18). Consequently, tension and dissension within the community increased while self-sufficiency declined.

Indications of social trauma, including violent deaths, alcohol abuse and child neglect all began to appear during the 1960's and 70's (Ideas, 1983: 28).

Discovery of mercury in fish and in the Native people themselves had several profound, adverse consequences. While only a few individuals in each community had mercury levels high enough to cause symptoms and, as noted, only a few evidenced symptoms that might be the result of methylmercury poisoning, the fear and anxiety from knowing they were contaminated was debilitating to many. The threat of mercury poisoning clearly affected the mental health of these people even if the medical evidence of any effects on their physical health was inconclusive.

The closure of the commercial fishery was a particularly serious blow. It denied the Indians a source of income, an important source of food, economic self sufficiency, a vigorous and healthful occupation and a feeling of self reliance and well-being.

Finally, as a result of the closure of Ball Lake Lodge in 1970 a number of band members lost their jobs as fishing guides. Guiding and commercial fishing are occupations that are compatible with both Native and non-Native lifestyles. Apparently, many of the Band members at Grassy Narrows had a long association with Ball Lake Lodge. As recounted in the Ideas program, "although the majority of guides managed to find at least part time employment in other lodges in the area, the end of Ball Lake Lodge spelled the end of a way of life" (Ideas, 1983: 24).

2.6 Benefits and Beneficiaries

Various public benefits that could result from accelerating the decline in mercury levels in fish can be identified. The beneficiary groups can also be identified. These benefit categories and the relevant beneficiaries are summarized in Table 2.2.

A reduction in mercury contamination in fish could lead to a reduced **health risk** among the Native people at the Whitedog and Grassy Narrows Bands because these people have the most opportunity and inclination to eat fish from contaminated water bodies. Any benefit in terms of reduced health risk to sport fishermen is judged to be slight because anglers eat comparatively little fish and because the sport fish eating guidelines are available. Other non-Native consumers of fish are not at risk because commercial fishing of contaminated fish is banned and the federal fish testing program is intended to prevent contaminated products from reaching consumers.

Commercial fishing is a second benefit category. Commercial fishing licenses and permits for the Wabigoon and English systems are generally held by Native people, who would benefit most from a full resumption of commercial fishing and increased production of uncontaminated fish.

A third potential benefit category is **food or subsistence fishing.** This activity, which is now curtailed, was generally carried out by Native people coincidentally with commercial fishing although many non-commercial Indian fishermen were also engaged in food fishing. Reduced mercury levels to below 0.5 ppm in fish would permit this activity to be resumed.

Sport fishing is a fourth benefit category. Current sport anglers, as well as new fishermen who might come to the region to fish, may experience greater utility or enjoyment from fishing if mercury levels in sport fish were lower.

Camps and lodges which depend on sport fishermen constitute another benefit category. Any increase in revenues and expenditures at these establishments that may be attributable to rehabilitation of the river system could translate into extra employment for local people as guides and housekeepers and extra profits to lodge owners.

Many people who may never visit the Wabigoon-English System, might derive greater satisfaction by just knowing that fish are no longer contaminated or that commercial and food fishing opportunities were restored. These are so-called **non-user** benefits.

Finally, improvements in commercial and food fishing and the reduced health risks could have **social benefits** that do not have a monetary value. The best that can be done is to describe them either qualitatively or quantitatively, to the extent that appropriate indicators are available.

TABLE 2.2

POTENTIAL PUBLIC BENEFITS OF REHABILITATION OF THE WABIGOON-ENGLISH-WINNIPEG RIVER SYSTEMS AND EXPECTED BENEFICIARIES

Potential Benefit Categories	Expected Beneficiaries
1. Reduced Physical and Mental Health Risk	Native People of Grassy Narrows and Whitedog
2. Increased Commercial Fishing	Native People of Grassy Narrows and Whitedog
3. Increased Food Fishing Opportunities	Native People of Grassy Narrows and Whitedog
4. Increased Sport Fishing Enjoyment and Participation Attract more Sport Fishermen Increased Business for Lodges	Current Anglers New or Potential Anglers Tourist Lodges and Camps
5. Non-user Benefits	Citizens of Ontario and Canada
6. Social Benefits	Native People of Grassy Narrows and Whitedog

CHAPTER 3

REHABILITATION OPTIONS AND COSTS

3.1 Rehabilitation Approaches

Several approaches to rehabilitating the English-Wabigoon River System and reducing the concentrations of mercury in fish have been proposed and are summarized in Table 3.1.

The cost implications and potential mercury reductions as a result of the options recommended by the Canada-Ontario Steering Committee are discussed in more detail below.

3.2 Recommended Options

The Canada-Ontario Steering Committee (1983) recommends the following remedial actions:

(1) "that the mercury monitoring and fish consumption guideline program be continued" (p.22);

(2) "a pilot project for semi-continuous resuspension of non-mercury contaminated sediment ("sediment mixing" - a variation developed by the Steering Committee on the clay covering option presented by Acres (1982)) into the system at critical points be conducted and assessed" (p. 23). Carried out in the following order:

(a) Deep sediments from eastern Clay Lake injected into western Clay Lake and downstream;

(b) Deep sediments from the north basin of Ball Lake injected into the English River; and

(c) Deep sediments from Wabigoon Lake injected into the Wabigoon River.

Site (a) should be undertaken first to be followed by (b) and (c) if mercury concentrations in fish decline after implementation of (a); and

(3) "The sediment between Dryden and Clay Lake be removed by dredging" (p.24).

TABLE 3.1

REHABILITATION PROPOSALS FOR THE WABIGOON-ENGLISH RIVER SYSTEM

OPTION	COST CAPITAL	ANNUAL O & M	YEARS TO IMPLEMENT	COMMENTS	SOURCE
1. Rerouting the Wabigoon River Between Dryden and Clay Lake			-	Not seriously being considered	Jackson, Parks and Rudd (1980)
2. Sediment Decontamination of Wabigoon River and Clay Lake					
a) Flushing	-	-	-	Sediments will be spread downstream; results of are very uncertain	Acres (1982) Parks et al (1984)
b) Dredging Wabigoon River	$20.4 Million	-	6	Remove wood waste sludge deposits	Acres (1982)
3. Cover Contaminated Sediments with Clean Sediment.	-	-	-	High flows would remove covering material in Wabigoon River	Acres (1982)
4. Sediment Mixing/Covering	$4-5 Million	-	-	Proposed only for Clay Lake; in addition to dredging	Acres (1982) Canada-Ontario Steering Committee (1983)
5. Reducing Condition Favourable to Methylation of Mercury	-	-	-	Not practical at this time	Parks et al (1984)
6. Reducing the Bio-availability of Mercury by resuspension of clean sediment	-	-	-	Recommended for further study	Parks et al (1984)

This recommendation would involve dredging much of the 80 km stretch of the Wabigoon River channel above Clay Lake beginning at Dryden. Dredging operations downstream of Clay Lake are not considered to be worthwhile.

Dredging would also remove organic wastes (wood fibre) which currently cause oxygen depletion of overlying waters. This would improve conditions in the Wabigoon River for fish and other aquatic life, as well as improve the aesthetic quality of the river.

The Canada-Ontario Steering Committee (1983: 25) also recommends that sediments behind the Wainwright dam be dredged and a clean, deep sediment cover be pumped over the remaining debris.

(4) **"Additional scientific investigations" (p. 26).**

- **Quantify the loss of inorganic mercury from the water to the atmosphere.**

- **Make further tests of the effects of selenium on mercury transport through the ecosystem.**

3.3 Cost Estimates of Recommendations

Cost estimates are available only for the dredging option based on the Acres Consulting Services Ltd. (1982) report. The fish testing and research recommendations are not examined in any detail because their costs will be modest and they will not contribute to any actual changes in the mercury contamination of fish.

Acres Consulting Services Ltd. (1982) examined two options for dredging. The first consisted of flushing the sediments below Wainwright dam to Clay Lake coupled with dredging behind the Wainwright dam to Dryden. The second scheme involved dredging the river bed from Dryden to Clay Lake. Acres Consulting Services Ltd. (1982: 62, 95) concluded that dredging is preferred to flushing and two alternative implementation plans for dredging are developed:

- with a Pilot Project; and
- no Pilot Project, but with monitoring and testing.

Either dredging alternative would take 6 years to complete. The actual dredging would start late in Year 3 without a Pilot Project and in early Year 4 with a Pilot

Project. Acres Consulting Services Ltd. (1982: 118) concluded that unless there are some non-engineering reasons for implementing the Pilot Project, sufficient information exists to proceed without it.

The cost estimates for dredging the Wabigoon River that were developed by Acres are representative of the Steering Committee's dredging recommendation and are used in this analysis.

The total cost of the six-year dredging project has been estimated to be $20.4 million in 1981 dollars. A $6.3 million contingency allowance has been included which implies that this proposal could cost as little as $14.1 million. The timing of the project expenses over the six-year period and the cost components of the dredging program are listed in Appendix B.

Because the dredging expenses would be incurred over six years, it is appropriate to discount these costs. At a 10% discount rate, the Present Value, based on the pattern of expenditure shown in Table B.2, would amount to about $13.5 million.

Acres Consulting Services Ltd. (1982: 76-79) also estimated that the "sediment mixing" project, which involves covering the remaining contaminated sediments in Clay Lake with 5 cm of clean material, would cost an extra $4.5 million. This cost would be contingent on having the dredging equipment already on site. It would cost considerably more to implement this project independently of the dredging since the the necessary equipment and manpower would have to be brought to the sites.

These cost estimates refer only to the dredging and "sediment mixing" components of the Steering Committee's recommendations. Dredging would eliminate mercury feedback from contaminated sediments in the Wabigoon River above Clay Lake. Covering contaminated sediments in Clay lake would eliminate or reduce mercury feedback from contaminated sediments in the lake. No estimate of the costs of the resuspension pilot projects is available.

Finally, in addition to these capital costs, there may be adverse effects associated with the dredging due to downstream siltation. For the covering and sediment suspension options, high turbidity and siltation would disrupt existing uses although Acres Consulting Services Ltd. (1982) suggested that this can be controlled.

3.4 Uncertainty about the Consequences of the Recommended Actions

The extent to which the remedial measures might accelerate the decline of average mercury levels in fish is uncertain.

The Canada-Ontario Steering Committee concludes that:

> "The degree of improvement of mercury levels in fish which would result from remedial action could not be determined from the study results, but the nature of the improvement would be to speed the rate of recovery (possibly by some 10 to 20 years), compared to the ongoing changes occurring in the system." (p. 10).

Further, the Canada-Ontario Steering Committee (1983: 22) states that:

> "... we expect that they (the recommendations) would result in a more rapid recovery of the system, but the degree of expected improvement of mercury levels in fish could not be determined closely."

As noted, Mackay and Paterson (1982) examined a number of dredging scenarios with their model. In each of the simulations, they found that mercury concentrations in fish in lakes downstream from Clay Lake did not change because of massive dilution from the English River. However, the Mackay and Paterson model indicated that dredging the river from Dryden to Clay Lake would result in an 84% reduction of mercury in young pike in Clay Lake within one year (Mackay and Paterson, 1982: 28).

Mackay and Paterson also examined the consequences of partially dredging the Wabigoon River from Dryden to the Eagle River Confluence. The effects of different removal efficiencies were also tested. These simulations indicated that mercury concentrations in young pike in Clay Lake could halve in 1-2 years and then halve again in 8 years, double the rate expected without dredging (Mackay and Paterson, 1982: 27). Achieving this rate of reduction depends on the removal efficiency of the dredging operation. It appears that an efficiency of 80% or better is necessary to achieve these results. Again, because of the dilution from the English River, these dredging programs are expected to have very limited effects on fish mercury levels in lakes on the English River part of the System.

In the absence of remedial measures, the Mackay and Paterson model predicts that it would take from 32 to 48 years to achieve a 65% reduction of mercury levels in young pike. Neary (1983) notes that Mackay and Paterson's model seriously underestimates the mercury concentrations in fish in the English River below Ball Lake. Consequently, based on the information available now, remedial measures could well have little effect on accelerating the decline in fish contamination throughout the river system.

Chapter 4

ANALYSIS OF BENEFITS AND COSTS

4.1 Quantification and Valuation of Benefits

Each benefit category is quantified to the extent possible. Recipient groups are identified and, where possible, the financial and amenity values of each benefit category are then estimated. Table 4.1 summarizes the beneficiaries, benefits and their relevant values. The potential benefits are estimated as if the remedial measures are fully effective.

However, Provincial/Federal scientific studies to date are inconclusive as to the outcome of recommended remedial measures. The studies have not provided estimates of the likelihood or probabilities concerning:

- the rate at which remedial measures will reduce mercury concentrations in fish;
- how low the concentration levels in fish will ultimately be; and
- whether the decline in mercury concentration levels in fish will be accelerated as compared with no remedial actions.

If the probability that the decline in mercury concentrations in fish will be accelerated after the remedial action is implemented is less than 100%, then the Expected Value of the benefits will be lower, as well. Indeed, the first point raises the question, will there be any public benefits attributable to the remedial measures?

The second source of uncertainty can actually limit which benefits will result from the program. If, for example, the average mercury concentrations level off at between 0.5 and 1 ppm, certain benefits will not accrue. If the average is 0.5 ppm or lower, additional types of benefits can result. Moreover, the farther into the future that benefits or costs are incurred, the lower the value people place on them today.

In the sections to follow, potential benefits will be discussed with the proviso that the above uncertainties could severely reduce the Expected Value of these benefits.

4.2 Health-Related Benefits

Health-related benefits consist of a reduction in or the prevention of mortality (deaths) and/or morbidity (illnesses) or the lowering of the risk of adverse mental

TABLE 4.1

POTENTIAL PUBLIC BENEFITS OF ACCELERATING THE DECLINE IN THE MERCURY CONTENT OF FISH IN THE WABIGOON-ENGLISH-WINNIPEG RIVER SYSTEM

Biophysical Effect or Receptor Category	Consequences of Mercury Contamination in Fish	Who is Affected?	Potential Benefit of Reducing Contamination[1]	Quantitative Dimensions	Financial Values	Amenity Values
1. Human Health	Increased blood mercury levels.	Native people of Grassy Narrows and Whitedog Reserves.	Reduced risk of future physical and mental illness to people on the Reserves.	1,400 Native people exposed to anxiety and mental illness.	Reduction in: - health care costs - cost of medical surveys.	Compensation Required (CR) by Native people to endure adverse health effects.
	Ten people may have neurological symptoms due to methylmercury.	No other groups appear to eat sufficient fish to affect health.	Reduced anxiety.	Fewer are exposed via fish consumption and actual methylmercury poisoning.	No data to make estimates.	WTP from "non-users" (e.g., the public or governments) to reduce future health risks.
	Anxiety and Aggravation of other health and psychological maladies.					No estimates available.
2. Commercial Fishing	Commercial fishing banned on specific lakes in 1970.	Native fishermen, mostly from Grassy Narrows and Whitedog Reserves.	Increased commercial catches of northern pike and walleyes for sale.	An additional 29,000 to 56,000 kg per year may be caught commercially.	Revenues and profits for commercial fishermen - annual revenues \$100,000 - undiscounted value over 20 yrs. - \$2M. - asset value at 10% = \$1 million.	WTP from "non-users" to provide employment opportunities to Native
	Fishing for whitefish permitted in 1977. Other gamefish still banned.			Up to 20-30 additional people could be employed.		No estimates available.
	Employment opportunities reduced.				Consumers' surplus from price reductions - none expected.	
3. Social Implications	Further social deterioration of Native Communities. Loss of employment.	Native people from Grassy Narrows and Whitedog Reserves.	Mercury poisoning only one of several causes of social disruptions. May not help social problems.	No data on social disruptions; e.g. - crimes, alcoholism, violence, etc.	Reduction in costs of social deterioration.	WTP of "non-users".
					No data to make estimates.	No estimates.

Table 4.1 (cont'd)

Biophysical Effect or Receptor Category	Consequences of Mercury Contamination in Fish	Who is Affected?	Potential Benefit of Reducing Contamination	Quantitative Dimensions	Financial Values	Amenity Value
4. Food Fishing	No food fishing permitted in contaminated lakes.	Native people from Whitedog and Grassy Narrows.	Food fishing by Native people may be resumed, but only for species with average Hg levels 0.2 ppm or less.	As much as 48,000 kg per year round weight could be harvested from the system for food.	Reduction in cost of frozen fish supply to government - annual savings = $35,000 - undiscounted value over 20 years = $700,000.	WTP from "non-users" to provide food fishing opportunities for Native people. No estimates available.
	Frozen fish must be supplied from outside sources and freezers maintained.	Provincial government.	Elimination of frozen fish supply program.			
5. Sport Fishing	Warnings about eating fish.	U.S., Canadian and Ontario sport anglers.	Increased satisfaction for existing fishermen. New anglers attracted to area.	No data available on current angler days or amounts of sport fish taken.	.... Added enjoyment and WTP by existing anglers. .... WTP of new anglers attracted to region. .... No data to make estimates.	
	Sportfish eating Guidelines.	Resident fishermen.	No evidence that either type of benefit will occur.			
6. Tourist Services	Two lodges closed, one re-opened.	Owners and employees.	Eliminate warning signs. Camps and lodges would benefit if new anglers came to region.	No data to make estimates of new anglers who might stay at camps and lodges.	Extra profits to lodge owner realized only if new anglers come to area.	Not applicable.
7. "Non-Users"	Bad image for province.	Citizens of Ontario and Canada as represented by governments.	Better image for province; achieve justice.	No data.	..... Governments appear to be willing to pay .... substantial sums to compensate Indian .... Bands and to provide social and .... economic assistance.	
	Feelings of responsibility and stewardship.		Altruistic Satisfaction.			

or physical health effects. These benefits would be measured as the number of deaths, illness cases or sick days avoided.

The relevant relationship between the proposed remedial measures and the potential changes in health effects consists of a number of complex relationships among:

- the quantity of fish consumption;
- the resulting body burden of mercury as indicated by blood levels;
- the sensitivity of the individual, and
- the detection of physical or mental health effects.

These relationships are based on the report on methylmercury by Health and Welfare Canada (1979), which indicates that the human body burden of mercury can be reduced by (a) curtailing the intake of contaminated food (fish) and (b) by a reduction in the mercury content of the food that is consumed. To date, the first strategy has been followed in order to protect human health.

The Native people of the Grassy Narrows and Whitedog Reserves are essentially the only people who might still eat enough fish from the system to affect their health. Consequently, they could benefit from a reduction in the mercury content of the fish. The general population, including sport anglers who fish the English-Wabigoon, is presumably protected by the fish eating guidelines, the ban on commercial fishing and the fish-products testing program carried out by the federal government. Consequently, the benefits of the dredging project to all but the people on the White Dog and Grassy Narrows Reserves, in terms of reduced health risk, appear to be negligible, given current information.

Even for the people in the two Native communities, the potential health related benefits from dredging are likely to be small for the following reasons:

(1) much of the damage has already been done. Health care and testing programs would have to continue even if mercury levels in fish were reduced;

(2) based on blood and hair testing programs, the number of people at risk with high blood mercury levels appears to be declining without remedial measures, presumably because the people are not eating as much contaminated fish; and

(3) Health and Welfare Canada (1979: 60) recommends that mercury concentrations in fish should be 0.2 ppm or lower before the people at Grassy Narrows and Whitedog can safely eat them.

While it appears that benefits in terms of reduced risk of mortality and morbidity are small to non-existent, a reduction in fish mercury levels could help to reduce the anxiety and mental trauma experienced by these people. Measures of this effect are not available.

Since health-related benefits of the dredging proposal are likely to be small or non-existent, the associated financial or amenity values are also small or non-existent. Reductions in anxiety, if they occur, would conceivably have an amenity value associated with them. Moreover, other people in Ontario who do not visit or fish in the system may be willing to pay to help protect the health and reduce the anxiety and anguish of the Native people. However, it is not altogether clear that the dredging project is the most effective way to accomplish these beneficial results for the two Native communities.

4.3 Commercial Fishing

The benefits associated with commercial fishing consist of the additional fish that can be caught and sold and the added employment and income that this activity would generate. Realization of these benefits depends on the accelerated achievement of a mercury level of .5 ppm or lower in the various species of fish as a result of the amelioration options.

The United States, Denmark, Holland and West Germany permit the sale of fish with mercury concentrations up to 1.0 ppm (Cowan, 1983). Commercial fishing for walleyes, pike and other game fish could conceivably be reinstated for fish with .5 to 1 ppm if these products are exported. However, it is not certain that the Ministry of Natural Resources, the commercial fishing licensing authority in Ontario, would issue permits or quotas for lakes with species which have average mercury levels greater than 0.5 ppm. Arrangements would also have to be made with the Federal Department of Fisheries and Oceans to permit these fish to be processed and exported.

"High", and "low" estimates of potential increases in commercial fish production were developed based on the variation in historical catch data. These estimates are shown in Tables A.4, A.5 and A.6 in Appendix A. The "high" estimate of the possible increase in commercial fish harvest is assumed to be the maximum annual catch that occurred in each lake before the ban **plus** a portion of the potential sustainable yield in contaminated lakes that were not commercially fished before the ban (e.g. Ball Lake and Indian Lake). Out of an estimated annual maximum sustainable fish yield of 173,000 kg (see Table A.3 in Appendix A) from previously fished lakes, the "high" estimate of the potential commercial catch amounts to 47,390 kg of fish annually.

In addition, if commercial fishing is permitted on Ball Lake and Indian Lake, lakes which were not commercially fished prior to 1969, it is assumed that commercial fishermen could catch about 50% of the total potential yield of each species (Table A.3 in Appendix A). As shown in Table A.6 (Appendix A), the theoretical extra yield that commercial fishermen might, therefore, achieve is 54,600 kg per year.

Resumption of pre-1969 levels of fish catches may provide some additional employment. If pre-1969 levels of commercial fishing could be resumed, this would require the issuing of additional licenses for Clay, Swan and Tetu Lakes and for the English River. Commercial licenses would also have to be issued for Ball and Indian Lakes in order to realize the so-called "high" estimate of total catch. At pre-1969 catch levels, an additional 15 to 25 people might be employed. With the addition of commercial fishing in Ball and Indian Lakes, a total of 20 to 30 extra people might be employed in commercial fishing. This tentative estimate is based on an average of 4 people per license.

A low estimate of the extra fish catch that could be produced is derived from the decrease in the mean annual catch from the contaminated waters of the system for each of the key commercial species (Table A.4 in Appendix A). Under this assumption, if commercial fishermen were to resume their average, pre-1969 catch levels, their total catch would increase only by about 29,000 kg per year. (Table A.5 in Appendix A.) About 24,000 kilograms of this increase consist of northern pike, walleyes, whitefish and tullibee.

Achievement of a "maximum" extra harvest of 54,600 kg per year will be mitigated by the following factors:

- uncertainty as to whether, and when, the average mercury level for each species of fish in each waterbody will decline to 1.0 ppm or 0.5 ppm;
- whether the Ministry of Natural Resources will grant licenses and quotas in all lakes and rivers and for all species;
- the potential yield figures are subject to revision as actual catch data are accumulated; and
- whether marketing facilities in the area can handle the extra harvest.

The financial value of the extra commercial fish harvest consists of:

- extra revenues or profits (e.g. producers' surplus) accruing to commercial fishermen; and
- extra benefit to consumers (consumers' surplus) that would result if the prices of fish were reduced because of the extra yield.

The financial value of the benefit to commercial fishermen is computed by multiplying the expected extra annual yield of each species by an appropriate market price. Prices are derived from the Ministry of Natural Resources (1982) data on fishing revenue for Northern Inland Waters. Fishermen will also incur extra costs for fuel, gear, equipment and possibly wages to harvest the fish. In addition, the Provincial government will likely incur extra fisheries management costs. All of these costs should be subtracted from the extra revenues to obtain the net financial value of the benefit to commercial fishermen.

However, because there is substantial unemployment in the region, the marginal (extra) cost of labour (wages) is assumed to be zero. Extra costs of gear and fuel will be positive, but are unknown at this time. The extra costs to the Ministry of Natural Resources for fisheries management services and protection and any other activities associated with the increased fish yield will also be positive, but are unknown, as well. Consequently, for purposes of this assessment, the extra revenues from the increased fish yield may represent a slight over-estimate of the extra profit to commercial fishermen. The resulting revenue estimate is an optimistic, but plausible, $100,000 per year. The total, undiscounted revenue over 20 years would be $2 million.

Discounting reduces this value considerably. If commercial fishing were to begin a year after the amelioration projects were completed, the present value of the $2 million in revenues, at a 10% discount rate, would be $951,356. If these benefits begin 5 years after the end of the amelioration project, the present value would be $619,396. If commercial fishing were not able to start until 50 years had elapsed, the present value of the subsequent 20 years of commercial fishing revenues would only amount to $8,505 at a 10% discount rate.

The asset value of the commercial fishing can also be estimated by dividing the annual revenues by an interest rate that could be earned if the funds for the project were invested elsewhere. At 10%, the capitalized value of the commercial fishery is $1 million. This means that the commercial fishery that could be restored might potentially

yield the same annual income as one million dollars invested in a bank at 10%.

In addition, there may be an amenity value associated with the restoration of commercial fishing on these river systems. As indicated in the Ideas program, the Native people regard commercial fishing as a component of their traditional way of life. Society may well be prepared to attribute an added value, over and above the financial value of commercial fishing, to restore commercial fishing opportunities. There is, however, no objective indication of what this amenity valuation might be at this time.

No change in consumer surplus is expected since prices of pike, walleye and other species of fish change seasonally and as a result of long-term demand shifts, not because of relatively small supply changes (Hough, Stansbury and Michalski Ltd., 1982: 79). Consumers would, therefore, not benefit in terms of lower fish prices.

4.4 Fishing as a Food Source for Native People

Food or subsistence fishing is another important component of the Indian lifestyle. However, this practice has been severely curtailed as a result of the mercury contamination. According to the recommendations of Health and Welfare Canada, the people on Grassy Narrows and Whitedog could enjoy unrestricted consumption of fish only if the mercury concentrations were reduced to 0.2 ppm, but the likelihood of achieving this level has not been determined.

Assuming that the mercury levels in fish decline sufficiently to permit the resumption of food fishing, how much fish yield would this activity produce? Lacking data on fish consumption by people at Grassy Narrows and Whitedog, estimates will be based on work by Hough, Stansbury and Michalski Ltd. (1982: 40-43) on the Lake of the Woods. It was estimated that the 1978 per capita fish consumption by 10 Indian reserves (with a total population of 1,677) on the Lake of the Woods amounted to 33 kg per person per year, round weight (the whole fish). Based on studies at James Bay (James Bay and Northern Quebec Harvesting Research Committee, 1976), the average edible portion of the fish consisted of 60% of the round weight or 20 kg per person per year (excluding canned fish products or fish purchased in restaurants). Statistics Canada (1981) and the Canada Department of Fisheries and Oceans (1980) reported that the apparent average annual consumption of fish (including canned and cured) in Canada totalled 6.03 kg per person per year, substantially less than the 20 kg estimated for the Indian people.

Using the round weight figure of 33 kg per person per year, the people on the Grassy Narrows and Whitedog Reserves could conceivably catch and eat as much as 47,880 kg per year, round weight, from the Wabigoon-English System. In fact, it is likely that they consume substantially less than this amount because some people eat less fish, they may catch fish from lakes off the system and fish caught from the formerly contaminated lakes will continue to be avoided by customers.

The financial value of food fishing would be the cost of replacing the food represented by these fish. The cost to the Provincial Government of programs to provide frozen fish with less than 0.2 ppm to the two bands has been between $25,000 and $35,000 per year. If amelioration methods were to be successful in reducing mercury levels in fish, the elimination of the annual cost of this program would be counted as a financial value benefit. Again the realization of this financial value depends on whether the mercury levels will decline faster than it would take naturally.

There may also be an additional value associated with the intangible aspects of a resumption in food fishing. Hough, Stansbury and Michalski (1982: 43) also found that food fishing offered a healthful supplement to band members' diets, particularly those with low cash incomes. For Native people, food fishing is part of their culture and has helped to strengthen their social fabric. Furthermore, other people in Ontario may be willing to pay something to help restore opportunities for food fishing from altruistic motivations. However, as with commercial fishing, there is no evidence as to whether, or how much, "non-users" might be willing to pay to help restore food fishing for Native people in the study region.

4.5 Sport Fishing

Reduced mercury levels could have both tangible and intangible benefits for sport fishing. Any increased desirability and enjoyment of fishing that anglers who are currently fishing the lakes and rivers of the system might experience would be an intangible or "amenity" benefit. If more anglers were attracted to the region as a result of the rehabilitation efforts, this would constitute a tangible benefit to camps and lodges in the area which would experience increased demand for their facilities and services and, hopefully, higher profits. This increased demand could also translate into increased economic activity in the region, as well as more employment for local people.

Based on the overnight capacities and occupancy rates of the lodges and camps on the system, an estimate of visitation to the area can be made. The season lasts from May 15 to September 15. Over this period, attendance at these establishments would be approximately 32,426 "visitor days". According to Ruston/Shanahan and Associates Ltd. et al. (1979: 18) 89% of the lodge and camp guests are U.S. visitors and 79% of these people give fishing as the primary reason for coming to the area. Thus, 28,860 visitor days could be from the U.S. and about 22,800 of this group are likely devoted to fishing.

Anglers coming into the area who do not stay in camps and lodges are not included. Thus, the figures underestimate total sport fishing participation.

Other potential sport fishing benefits require further research to determine their nature and value. Publicity concerning the rehabilitation effort could possibly attract more anglers to the region. A Ministry of Natural Resources official in Kenora was of the opinion that mercury contamination has not been a limiting factor to tourism and recreational angling in recent years (G. Winterton, March 25, 1982). However, a Ministry of Tourism and Recreation official in the area argued that it would be beneficial to tourism in the region if the proposed clean-up of the river system can be accomplished to the extent that signs which warn people that fish are contaminated could be removed (W.R. McRae, 1982). The official also noted that foaming and discolouration in the Wabigoon River from the Dryden mill are still evident at various road access points along the river. The consequence of these effects on tourism is, however, not known.

It is also likely that anglers are more attracted to a location by increased fishing quality and angling success rather than by reduced contamination. This is possible because the fishing experience is as much the product of fishing as is the fish itself.

It has been suggested that additional camps or lodges could be constructed on the English or Winnipeg River-Lake systems if mercury contamination were eliminated from fish. Although there is no evidence of any plans or intentions by anyone to establish new resorts or tourist facilities in this area, the Ministry of Natural Resources has indicated that they would like to re-direct sport fishing to the English-Winnipeg Lake systems in order to reduce pressures on the Lake-of-the-Woods.

The financial values associated with the tangible (new visitors) and intangible (increased satisfaction for current fishermen) benefits of recreational fishing are the extra revenues that lodges, camps and other businesses in

the region might receive, less payments to firms outside the region for goods and services used by the recreational businesses. This monetary value is sometimes referred to as "net regional revenues". Since many of the visitors to the region are from the U.S. or Manitoba, the net financial value to Ontario could well be positive.

Numerous studies have shown that there is a substantial and measurable amenity value associated with recreational fishing (Freeman, 1979: Ch. 8). This value would be the maximum amount of money anglers are willing to pay per day of fishing, less whatever they have to pay for licenses, travel, accommodation, etc., in order to access the fishery. This excess of willingness-to-pay over expenses incurred is measured by consumers' surplus.

For current anglers, the extra consumers' surplus they might gain from the "cleaner" fish is the monetary measure of their satisfaction. For potential anglers, the total consumers' surplus (e.g., total willingness-to-pay less all expenses) per day of fishing is the relevant amenity value. Both values could be determined by means of specially designed surveys.

Estimates of the current financial and amenity values associated with recreational angling on the English, Wabigoon and Winnipeg systems are not available. Further research would be required to estimate the financial values of possible extra profits to local businesses as well as the amenity values of current and potential anglers.

Hough, Stansbury and Michalski (1982: Ch. 3) prepared detailed estimates of the financial and amenity values of the Lake-of-the-Woods fisheries. That study encompassed all types of lake users including Indians, local non-Indians, commercial fishermen and recreational anglers. The net monetary value per angler for tourist, accommodation-based recreational angling was estimated to be $10.00 or more, by far the highest value of any of the different uses examined by the Hough, Standbury & Michalski Study. These estimates can only serve as a reference point since they cannot be extrapolated directly to recreational angling on the Wabigoon-English system.

4.6 Economic Activity Effects

Expenditures to implement a dredging project in the Wabigoon River will create employment and economic activity in the region. These consequences are not normally counted as benefits to be compared against costs since employment on construction and dredging operations is only temporary. Increases in permanent employment, such as commercial

fishing, add to the wealth and economic welfare of a region.

Moreover, an increase in spending by government in one region will often be offset by equal reductions in spending somewhere else. In this case, the tax dollars which would be spent on rehabilitation of the Wabigoon would have been spent elsewhere by the provincial government.

Nevertheless, economic activity and jobs that are generated by the project expenditures, however temporary, are important economic windfalls to the people of the particular region.

The expected distributional pattern of spending the project costs was provided by Acres Consulting Services Ltd. (1982). Approximately 55% of the total cost is expected to be spent in the Dryden area, 32% elsewhere in Ontario and 13% outside Ontario. Expenditures in the Dryden area will be almost entirely for labour and local contractors.

The employment effects of these expenditures are not clear since it is not known just how many local people will be hired to work on the project. In order to ensure local benefits, it may be possible to make hiring of local (Native and non-Native) people a condition of contracts if any of the remedial projects proceed.

4.7 Reduction in Social Disruptions

Commercial and food fishing are important components of the Indian lifestyle. Mercury contamination and the subsequent loss of these activities coupled with relocation, flooding of wild rice and fishing areas and the lack of clear hunting, trapping, fishing and forestry rights have all but eliminated opportunities for the Whitedog and Grassy Narrows bands to be self-sufficient. Alcoholism, drug abuse, idleness, child neglect and violence have become common occurrences in these communities and are indicative of the social disintegration that has plagued the two reserves (Speirs, 1983).

Band leaders emphasize that a wide variety of issues must be addressed and resolved in order to rehabilitate the two communities. Development of employment opportunities, compensation for losses sustained from the flooding and clear rights of access to natural resources are incorporated into the draft agreements being negotiated with the federal and provincial governments by the two Bands. Most of the provisions of the agreements concern other issues and resources that are not directly affected by mercury contamination.

As described in Appendix C, a compensation agreement has been reached among the two Bands, the governments and the two paper companies totalling over $16.7 million. These agreements and programs also provide an indication of how much society is willing to pay to enhance opportunities for these communities and how much the victims of the mercury pollution require in compensation to offset the adverse effects.

However, it is not clear whether dredging the river system would actually help the social recovery of the two Native communities. A resumption of commercial fishing for presently contaminated game fish species and unrestricted availability of food fish from the lakes and water courses would complement certain provisions of the agreements but none of the provisions is contingent on the successful implementation of the dredging project. Moreover, none of the costs to the governments specified by the settlement would be offset or replaced by a dredging program.

Until more is known about the relative importance that people in the White Dog or Grassy Narrows communities themselves place on commercial and food fishing opportunities, it does not appear that there are any extraordinary social benefits from a successful implementation of the remedial measures.

On the other hand, the compensation package may be used to develop employment and Native lifestyle opportunities similar to those that could result from a successful rehabilitation of the river system. If this happens, then the beneficial consequences to the people in the two communities of the compensation program would be far more certain than those from the dredging program.

4.8 Cost-Benefit Comparisons

Based on information developed in Chapter 3, the dredging program recommended by the Steering Committee would cost the Province of Ontario at least $20 million. This money would be spent over six years. The annualized value of this capital expenditure, if spread over 20 years at a 10% interest rate, amounts to $1.58 million per year. The present value of $20 million in Year "1" of the project, again using a 10% discount rate and assuming the installation schedule shown in Table B.2, would amount to $13.5 million.

For an additional capital cost of $4 to $5 million, the contaminated sediments in Clay Lake can be covered with clean material (Acres Consulting Services, 1982:79). If the recommended resuspension experiment is implemented,

total program costs will be higher although they are unknown at this time.

As shown in Table 4.1, the financial values associated with the benefits of a dredging program could amount to over $135,000 per year or about $2.7 million (undiscounted) over 20 years. About $100,000 per year would accrue to commercial fishermen, primarily Native people. The Provincial Government would save $35,000 annually by discontinuing the frozen fish program. However, this benefit would depend on whether fish mercury levels could be reduced to 0.2 ppm or lower. Amenity values may be attributed to human health, commercial fishing, food fishing and recreational fishing but the realization of these benefits are in doubt and no estimates of such values could be made without further empirical research.

4.8.1 Annualized Costs and Benefits

Compared with the estimated $1.58 million in annual costs, benefits worth $135,000 per year constitute a very poor return. However, in a case like this, costs are finite and most will be incurred during the first 5 or 6 years of the project. On the other hand, benefits are generated each year in perpetuity. Consequently, a comparison of the present values of the total costs and benefits is more appropriate than the annualized figures.

4.8.2 Net Present Values

As discussed in Section 4.3, commercial and food fishing benefits are not likely to be realized for some years after the completion of the project. Timing is critical to the estimation of the values of the various benefits because the timing will dictate how many years of annual benefits are realized and the extent of discounting, if it is to be applied.

Assuming a 30-year planning horizon, the undiscounted financial values of the benefits for specific periods of time are calculated in the following manner. It will take six years to complete the dredging. Based on the MacKay and Paterson model, commercial and food fishing benefits would not be realized until four years after completion of the project or a total of 10 years after the project has started. Benefits could be realized for the next 20 years out of a total 30-year period. If commercial and food fishing cannot start until nine years after completion of the project, then the benefits can be realized for only 15 years out of the 30-year period, and so on. The

undiscounted financial values of sport and food fishing under these assumptions are summarized below:

20 years of benefits x $135,000 p.a. =	$	2.7 million
15 years of benefits x 135,000 p.a. =		2.025 million
10 years of benefits x 135,000 p.a. =		1.35 million
5 years of benefits x 135,000 p.a. =		.675 million

Discounting will reduce the present values of these amounts.

Certain financial values and the amenity values which may be associated with commercial and food fishing, sport fishing and reduced health effects could be substantial, but they are unknown at this time. Nevertheless, one can, by deduction, determine the value that would have to be assigned to the amenity values and the unquantified financial values in order to justify the expenditure on the remedial measures. Using $13.5 million as the net present value of the project cost, the net present value of the quantifiable financial benefits of $135,000 annually, at a 10% discount rate for 20 years, is $1 million. The amenity and unquantified financial value benefits would have to be valued at $12.5 million if the project is to be regarded as economically viable. This figure also provides a benchmark with which to compare the results of any further studies of the values of these potential benefits.

4.8.3 Asset Values

A final comparison is the capitalized value of the fishery. Based on the $135,000 financial value attributed to commercial and food fishing, the asset value of the fish resource depends on the rate of return that can be expected from alternative uses of the project funds. Rates of return on investments such as government bonds, bank accounts, mutual funds or stocks currently range from 7% to 15%. Therefore, the capitalized, or asset, value of the fishery ranges as follows:

% Rate of Return	Asset Value
7	$1.9 million
10	1.35 million
12	1.125 million
15	.9 million

These figures imply that a maximum of $2 million should be invested in the project if only $135,000 worth of benefits were to be derived from the project each year. On the other hand, the annual value of the benefits from a $20 million investment would have to be between $1.5 million and $3.0 million per year to produce an equivalent return on investment implied by the 7% and 15% interest rates.

Table 4.2 summarizes these benefit-cost comparisons. The Net Present Value comparison yields the most comprehensive benefit-cost assessment. Nevertheless, presented by themselves, these financial comparisons omit important qualitative information and considerations.

The conclusions and recommendations presented in the next chapter are based upon the material in the previous chapters, as well as the comparisons displayed in Table 4.2.

TABLE 4.2

SUMMARY OF BENEFIT-COST COMPARISONS OF THE DREDGING OPTION FOR THE WABIGOON-ENGLISH RIVER SYSTEM

1. Annualized Costs and Benefits
(Calculated at 10% over 20 years)

Project Costs	=	$1.58M
Financial Value Benefits	=	$0.135M
		-$1.445M

2. Present Value of Costs and Benefits
(Using a 10% discount rate over 20 years)

Costs	=	$13.5 M
Benefits	=	$ 1.0 M
		-$12.5 M

At least $12.5 M must be attributed to amenity and unquantified financial benefits in order to make the project economically feasible.

3. Asset Value

Based on $135,000 annual value of benefits

Interest Rate	Asset Value of $135,000/yr	Annual Return Required on $20 M Asset
7	$ 1.9 M	$ 1.4 M/yr
9	1.5 M	1.8 M/yr
10	1.35M	2.0 M/yr
12	1.1 M	2.4 M/yr
15	0.9 M	3.0 M/yr

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 All benefits of the remedial actions depend on the extent to which reductions in mercury levels in fish in the river systems will be accelerated beyond what is occurring naturally.

5.1.2 The potential public benefits of the recommended remedial actions and their beneficiaries include:

a. reduced **physical** and **mental health risks** to the Native people of the Grassy Narrows and Whitedog Reserves;

b. increased **commercial fishing** and opportunities and catches for Native people of Grassy Narrows and Whitedog;

c. increased **food-fishing** opportunities and catches for Native people of Grassy Narrows and Whitedog;

d. increased **sport fishing** enjoyment by current anglers and the attraction of new anglers to the area. Possible increased revenues and profits to tourist services such as fishing lodges and camps and the employment of fishing guides;

e. **non-user** benefits in terms of increased satisfaction to the citizens and Governments of Ontario and Canada in knowing that the mercury contamination has been reduced and that the other benefit categories have been achieved;

f. **social benefits** in terms of reduced social disruptions to the Native People of Grassy Narrows and Whitedog;

g. the simultaneous removal (by dredging) of organic wastes (wood fibre) with the mercury from the Wabigoon River. Organic wastes cause oxygen depletion of overlying waters so that their removal would improve conditions in the river for fish and other

aquatic life as well as the aesthetic quality of the River.

These benefits can be realized only if remedial actions are successful in accelerating the reduction of mercury concentrations in fish to target levels.

5.1.3 The cost of the proposed dredging project (Dryden to Clay Lake) is about $20 million, to be spent over 5 or 6 years, and presently to be borne by the Government of Ontario. No detailed cost estimates were available for any of the other recommended actions.

5.1.4 Given available information, it was only possible to make quantitative estimates, as well as associated monetary values, for commercial and food fishing.

5.1.5 Data and information are not sufficient to produce estimates of sport fishing or of non-user benefits and their monetary values.

5.1.6 Data are insufficient to make quantitative estimates of health effects and their monetary values at this time. Nevertheless, health benefits, as a result of the rehabilitation project, are judged to be small.

5.1.7 Any extra income and employment in the Dryden area that would be generated by the dredging project expenditures will have temporary effects and are not a part of the net benefits of the project.

5.1.8 The results of preferred remedial actions (dredging of the Wabigoon River and sediment covering in Clay Lake) are highly uncertain. A review of the Technical Report of the federal-provincial research program and the Canada-Ontario Steering Committee Summary Report (1983), as well as discussions with various authorities, provided no estimates of:

a. the extent to which the decline in mercury concentrations in different fish species would be accelerated; and

b. the probabilities that average or mean mercury concentrations in fish species would reach levels whereby benefits could be realized (i.e., 0.5 ppm or lower), and no

estimates of when, if ever, these benefits would be realized.

Consequently, the technical feasibility of the project would be in doubt.

5.1.9 Because it is highly uncertain whether dredging will accelerate the decline in the mercury content of the fish, realization of the benefits discussed in Chapter 4 is uncertain, as well.

5.1.10 The Native people on the Grassy Narrows and Whitedog Reserves have suffered severe social disruptions over the years, only some of which can be directly attributed to the mercury pollution. River system rehabilitation efforts will not overcome many of these disruptions.

5.1.11 Benefit-Cost comparisons indicate that, even if all potential benefits were realized with complete certainty, decision-makers would have to attribute over $12 million, in present value terms, to some potential amenity benefits and to any, as yet unknown, benefits associated with sport fishing in order to make the dredging economically feasible.

5.1.12 At this time, there is little economic justification for the dredging option, particularly in light of the uncertainties as to whether environmental improvements would be realized.

5.1.13 If part of the compensation package is devoted to rebuilding employment and Native lifestyle opportunities, the beneficial results would be more certain than those that might result from the dredging project.

5.2 Recommendations

5.2.1 Given the degree of uncertainty about the biophysical and economic benefits, the dredging option should not be implemented at this time.

5.2.2 Further research on the river systems should focus on the following topics:

- determining the rate of decline in mercury concentrations in different fish species that would result from sediment removal, covering sediments or resuspension of clean material;

- obtaining data on sport fishing participation and on tourist service and lodge operations; and

- surveying Native communities and lodge owners to obtain further information for quantifying and valuing potential benefits.

BIBLIOGRAPHY

Acres Consulting Service Ltd. Studies on Moving Sediments in the Wabigoon River, 1982.

Anonymous. "Natives accept compensation pact for mercury pollution in Whitedog", Globe and Mail, March 27, 1982.

Bishop, J. N. and Neary, B. P. Mercury Levels in Fish from Northwestern Ontario, 1970-1975. Toronto: Laboratory Services Branch, Ontario Ministry of the Environment, 1976.

Canada Department of Fisheries and Oceans. Annual Statistical Review of Canadian Fisheries, 1978. Ottawa: Fisheries and Oceans Canada, 1980

Canada-Ontario Steering Committee. Mercury Pollution in the Wabigoon-English River System, and Possible Remedial Measures: Summary of the Technical Report. Ontario Ministry of the Environment, Environment Canada, 1983.

Cowan, T. Canada Department of Fisheries and Oceans, Personal Communication, Nov. 1983.

Desvousges, William H. and Smith, V. Kerry. Benefit-Cost Assessment Handbook for Water Programs - Volume I. Research Triangle, N.C.: Research Triangle Institute, April 1983.

Fimreite, N. and Reynolds, L.M., "Mercury Contamination of Fish in Northwestern Ontario", Journal of Wildlife Management, 1973, Vol. 37, pp 62-68.

Freeman, A. Myrick, III. The Benefits of Air and Water Pollution Control : a Review and Synthesis of Recent Evidence (a report prepared for the U.S. Council on Environmental Quality) Washington, D.C. : Council on Environmental Quality, December 1979.

Freeman, A. Myrick, III. The Benefits of Environmental Improvement - Theory and Practice. Baltimore, Md.: Johns Hopkins University Press for Resources for the Future, 1979.

German, M. J. A Water Pollution Survey of the Wabigoon River. Toronto: Biology Branch, Ontario Water Resources Commission, 1969.

Halvarsen, Robert and Ruby, Michael G. Benefit-Cost Analysis of Air Pollution Control. Lexington, Mass.: D. C. Heath and Co., 1981.

Hambly, Jo Anne. "English-Wabigoon Economic Development Project 1978-1980". Toronto: Ministry of Northern Affairs, April 1980.

Health and Welfare Canada, Medical Services Branch, Department of National Health and Welfare, Mercury Program findings to Dec. 31, 1978. Methylmercury in Canada. Ottawa: Dept. of National Health and Welfare, Dec. 1979.

Health and Welfare Canada. Methylmercury in Canada - Exposure of Indian Residents to Methylmercury in the Canadian Environment. Ottawa: Minister of National Health and Welfare, Medical Services Branch, December 1979.

Hough, Stansbury and Michalski Ltd. The Lake of the Woods Fishery - A Social and Economic Analysis. Toronto: Ontario Ministry of Natural Resources, April 1982.

Hufschmidt, Maynard M., James, David E., Meister, Anton D., Bowen, Blair T. and Dixon, John A. Environment, Natural Systems and Development - An Economic Valuation Guide. Baltimore, Md.: The Johns Hopkins University Press, 1983.

Ideas, "Under Attack: In Grassy Narrows", Transcript of a Radio Program, Toronto: CBC Transcripts, CBC Enterprises, 1983.

Jackson, Togwell A., Parks, J. W. and Rudd, J. W. M. "Introduction: The Problem of Mercury Pollution in the Wabigoon-English River System" in Togwell A. Jackson, ed. Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario and Possible Remedial Measures - A Progress Report for 1978-1979. Wabigoon-English River Mercury Study Steering Committee, April, 1980.

Jackson, T. A., Parks, J. W. and Rudd, J. W. M. "Discussion with Tentative Conclusions and Recommendations, Based on Results of the 1978-79 Study of Mercury in the Wabigoon River System" in Togwell A. Jackson, ed. Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario and Possible Remedial Measures - A Progress Report for 1978-1979. Wabigoon-English River Mercury Study Steering Committee, April 1980.

Jackson, T.A., Parks, J.W. Jones, P.D., Waychuk, R.N., Sutton, J.A. and Hollinger, J.D. "Mercury Pollution in the Wabigoon River System" in Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures - Technical Report. Ministry of Supply and Services, Canada, 1984. pp. 353-388.

James Bay and Northern Quebec Harvesting Research Committee. Research to Establish Present Levels of Harvesting by Native Peoples of Northern Quebec. Part I. A Report on the Harvests by the James Bay Cree. 2 vols., Montreal, 1976.

Keeney, Ralph L., Beley, J.R., Fleischaur, P., Kirkwood, C.W. and Sicherman, A. Decision Framework for Technology Choice - Vol. I: A Case of One Utility's Coal-Nuclear Choice. EPRI EA-2153, Palo Alto, Calif.: Electric Power Research Institute, Dec. 1981.

Mackay, D. and Paterson, S. "Mercury Modelling in the Wabigoon/English River System." Report prepared for the Ontario Ministry of the Environment, 1982.

Maler, Karl G. and Wyzga, Ronald E. Economic Measurement of Environmental Damage. Paris: OECD, 1976.

McAllister, Donald M. Evaluation in Environmental Planning - Assessing Environmental, Social, Economic and Political Trade-offs. Cambridge, Mass.: The MIT Press, 1980.

McGregor, D. B., District Manager, Kenora District, Ministry of Natural Resources, Letter of March 25, 1982 to the author.

McRae, W. R., Tourism Development Consultant, Ontario Ministry of Industry and Tourism, Letter of March 17, 1982 to the author.

North, D. Warner and Balsom, William F. "Risk Assessment and Acid Rain Policy: A Decision Framework that Includes Uncertainty" in Paulette Mandelbaum, ed. Acid Rain - Economic Assessment. New York: Plenum Press, 1985. pp. 163-182.

Ontario. Health Implications of Contaminants in Fish. Toronto: Ontario Ministry of the Environment, 1978.

Ontario Ministry of Health. Personal Communication, 1983.

Ontario Ministry of Natural Resources. Personal communications from the Kenora District Office, 1982.

Ontario Ministry of Northern Affairs. Personal Communication, March 15, 1982.

Ontario Ministries of the Environment and Natural Resources. Guide to Eating Ontario Sport Fish, published annually.

Parks, J. W., Sutton, J. A. and Hollinger, J. D. "Mercury Contamination of the Wabigoon/English/ Winnipeg River System - Causes, Effects and Possible Remedial Measures" in Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures - Technical Report. Ministry of Supply and Services, Canada, 1984. pp. 1-352.

Reeder, Stewart W., Demayo, Adrian and Taylor, Margaret C. Guidelines for Surface Water Quality - Vol. 1 Inorganic Chemical Substances - Mercury. Ottawa: Inland Waters Directorate, Environment Canada, 1979.

Rees, R. The Economics of Investment Analysis. Civil Service College Occasional Paper No. 17. London: Her Majesty's Stationery Office, 1973.

Rudd, John W.M., Turner, Michael A., Furutni, A., Klaverkamp, J.E., Townsend, B.E. and Swick, A. "Factors Controlling Mercury Bioaccumulation in Aquatic Ecosystems" in Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures - Technical Report. Ministry of Supply and Services, Canada, 1984. pp. 389-538.

Ruston/Shanahan & Associates Ltd., Hough, Stansbury & Associates Ltd., and Jack B. Ellis and Associates Ltd. The Fishing Hunting Lodge Industry in Northern Ontario. Toronto: Ontario Government (Ministries of Industry and Tourism, Natural Resources and Treasury and Economics), January 1979.

Speirs, Rosemary. "MPPs Describe 'Malign Neglect' of Ontario Indians", The Globe and Mail, October 25, 1983, p. 12.

Statistics Canada. Apparent per Capita Food Consumption in Canada, Part 1. Catalogue No. 32-229, Ottawa, 1981.

Toronto Star. "Band Approves Polution Settlement." Monday, Dec. 9, 1985, p. A18.

Toronto Star. "Grassy Narrows Okays Mercury Compensation." Thursday, Dec. 12, 1985, p. A12.

Troyer, Warner. _No Safe Place_. Toronto: Clarke, Irwin & Co. Ltd., 1977.

Ward, Olivia. "Indian Reserve Crumbles as it Waits for Help", _Toronto Star_, October 23, 1983, pp. A1, A8.

World Health Organization. _Environmental Health Criteria I. Mercury_. Geneva: World Health Organization, 1976.

APPENDIX A

COMMERCIAL FISH CATCHES ON THE ENGLISH-WABIGOON

ACTUALS AND ESTIMATES

TABLE A.1

ONTARIO LANDINGS BY COMMERCIAL FISHERMEN FROM LAKES IN WABIGOON-ENGLISH AND WINNIPEG RIVER SYSTEMS, 1961-69

Total Landings, All Species		Landings of Major Species (kg)				
		Tullibee (Cisco)	Northern Pike	Suckers	White fish	Walleye (Pickerel)
1961	- 37,903	927	5,796	7,528	13,181	8,285
1962	- 74,858	255	18,964	8,172	19,242	23,872
1963	- 61,616	1,208	17,560	4,980	12,409	22,615
1964	- 38,442	2,064	11,371	32	9,831	13,219
1965	- 44,102	661	13,217	4	10,516	13,154
1966	- 60,707	14,502	15,692	2,712	13,426	13,772
1967	- 17,455	174	4,223	444	5,079	4,132
1968	- 29,151	284	5,340	3,550	10,776	7,776
1969	- 58,651	3,398	10,440	4,581	23,034	13,282
Mean	46,987	2,608	11,400	3,556	13,055	13,345
S.D.	18,266	4,580	5,448	3,074	5,292	6,505

Source: Ontario Ministry of Natural Resources, Kenora District. Records on annual historic fish harvests for the English River and the following lakes: Clay, Separation, Grassy Narrows, Fox/Lount, Goshawk, Umfreville, One Man and Swan/Tetu.

TABLE A.2

ONTARIO LANDINGS BY COMMERCIAL FISHERMEN FROM LAKES IN THE WABIGOON-ENGLISH AND WINNIPEG RIVER SYSTEM, 1970-81

		Landings of Major Species				
	Total Landings All Species: (kg)	Tullibee (Cisco)	Northern Pike	Suckers (kilograms)	White fish	Walleye (Pickerel)
1970 Separation, Fox and Lount Lakes	13,070	15	1,438	1,777	8,057	1,701
1971 -	-	-	-			-
1972 -	-	-	-			-
1973 -	-	-	-			-
1974 -	-	(NO FISHING PERMITTED)				-
1975 -	-	-	-			-
1976 -	-	-	-			-
1977 -	-	-	-			-
1978 all lakes harvested again	18,276	350	776*	883	15,205	182*
1979 all lakes	20,704	2,079	5,415*	3,279	9,504	65*
1980 all lakes except Umfreville	27,467	1,576	3,541	2,048	17,205	3,387
1981 all lakes except Umfreville and Grassy Narrows	6,089	341	223	336	5,120	69
1970-81 Mean	17,121	872	2,279	1,665	11,018	1,081
1970-81 S.D.	8,052	900	2,158	1,134	5,041	1,463
1978-81 mean	18,134	1,087	2,489	1,637	11,759	926
1978-81 S.D.	8,922	880	2,432	1,307	5,498	1,642

* Used as fertilizer only.

Source: Ontario Ministry of Natural Resources, Kenora District. Records on annual historic fish harvests for the English River and the following lakes: Separation, Grassy Narrows, Fox/Lount, Goshawk, Umfreville, One Man, Swan/Tetu.

TABLE A.3

POTENTIAL FISH YIELDS AND CURRENT (1980) COMMERCIAL FISHING QUOTAS FOR CONTAMINATED LAKES ON THE WABIGOON-ENGLISH-WINNIPEG RIVER SYSTEM

Lake or River	Area (ha)	Total Potential Yield	Potential Yield*** by Species (kilograms per year)				Commercial Fishing Licenses (1980)	Quotas	
			Pike	Walleye	Whitefish	Small Mouth Bass	Issued to	Species	kg/year
WABIGOON RIVER (below Dryden)		2,000**	-	-	-	-	-	-	-
Clay Lake*		6,400	-	-	-	-	-	-	-
Ball Lake	2,571	8,065	1,210	1,936	1,855	-	-	-	-
ENGLISH RIVER*	4,925	14,824	1,482	2,965	2,965	1,482	-	-	-
Indian Lake	1,839	6,285	943	1,508	1,446	629	-	-	-
Grassy Narrows Lake*	3,613	14,653	1,465	2,931	2,931	1,465	Band	Whitefish	5,455
Fox/Lount Lakes*	5,398	18,693	1,896	3,739	3,739	1,869	Band	Whitefish	2,273
Separation Lake*	4,895	17,488	1,749	3,498	3,498	1,749	Band	Whitefish	4,545
Umfreville/Oneman Lakes*	11,105	25,762	2,576	5,152	5,152	2,576	Band	Whitefish	16,818
Goshawk Lake*	1,742	4,099	410	820	820	410	Band	Whitefish	1,364
WINNIPEG RIVER	7,307	28,598	2,860	5,720	5,720	2,860	11 Individuals	Whitefish	2,727 + personal use

* Footnotes at end of Table.

cont'd....

TABLE A.3 (cont'd)

Lake or River	Area (ha)	Total Potential Yield	Potential Yield by Species (kilograms per year)				Commercial Fishing Licenses (1980)		
			Pike	Walleye	Whitefish	Small Mouth Bass	Issued to	Quotas Species	Quotas kg/year
Tetu Lake*	4,400	18,084	4,159	2,713	4,340	-	-	-	-
Swan Lake*	1,194	10,012	1,341	2,682	2,682	1,341	-	-	-
TOTAL	48,989	172,963**	20,064	33,664	33,521	14,381		Whitefish	33,182 + personal

* These lakes had recorded commercial fish harvests prior to 1970.

** Potential fish yield cannot be achieved in the Wabigoon River because wastewater discharges from the mill at Dryden destroy the fish habitat between Dryden and Clay Lake. Total omits Wabigoon River.

*** The potential yield estimates are theoretical estimates based on 40% of the yield calculated from the Morphoedaphic Index (MEI). Where there has been sustained historical commercial fish harvesting at levels greater than these theoretical amounts, quotas have been allowed to reflect this.

Sources: Potential Yields - Ministry of Natural Resources, Kenora District Office.
Commerical Fishing Licence Data - Ministry of Natural Resources, Kenora District Office.

TABLE A.4

SUMMARY OF COMMERCIAL CATCH STATISTICS FOR WABIGOON-ENGLISH AND WINNIPEG RIVER SYSTEM

Species	Mean (kg/year)	%	Standard Deviation (kg/year)	(S.D. as a % of mean)	Maximum Annual Catch (kg/year)	Minimum Annual Catch (kg/year)
1961 - 1969						
Total Catch**	46,987	100	18,266	(38.9)	74,858	17,455
Northern Pike	11,400	24	5,448	(47.8)	18,964	4,223
Walleyes	13,345	28	6,505	(48.7)	23,872	7,776
Whitefish	13,055	28	5,242	(40.5)	23,034	5,079
Tullibee	2,608	6	4,580	(175.6)	14,502	174
Subtotal	40,408				80,372	
1978 - 1981						
Total Catch**	18,134	100	8,922	(49.2)	27,467	6,089
Northern Pike	2,489	14	2,432	(97.7)	5,415*	223
Walleyes	926	5	1,642	(177.3)	3,387	65*
Whitefish	11,759	65	5,498	(46.8)	17,205	5,120
Tullibee	1,087	6	880	(81.0)	2,079	341
Subtotal	16,261				28,086	

* Used as fertilizer only.

cont'd...

Table A.4 (cont'd)

Decrease from 1961-1969 to 1978-1981

	Mean	(% decrease)	Maximum Annual Catch	Minimum Annual Catch
Total Catch**	28,853	(-61.4)	47,391	11,366
Northern Pike	8,911	(-78.2)	13,549	4,000
Walleyes	12,419	(-93.1)	20,485	7,711
Whitefish	1,296	(- 9.9)	5,829	(+ 41)
Tullibee	1,521	(-58.3)	12,423	(+167)
Sub-total	24,147		52,286	

** The sum of the catches for the four species does not equal "Total Commercial Catch" because there are other species included which are not reported individually.

Source: Ontario Ministry of Natural Resources, Kenora District. Records of annual historic fish harvests for the English River and for the following lakes: Clay (1961-1969), Separation, Grassy Narrows, Fox/ Lount, Goshawk, Umfreville, One Man, and Swan/Tetu.

TABLE A.5

"LOW" AVERAGE ESTIMATED INCREASE IN ANNUAL COMMERCIAL YIELD

Total Commercial Catch	28,900 kg
Northern Pike	8,900 kg
Walleyes	12,400 kg
Whitefish	13,000 kg
Tullibee	1,500 kg

TABLE A.6

"HIGH" EXTRA FISH YIELD FROM THE WABIGOON-ENGLISH-WINNIPEG RIVER SYSTEM

Species	Maximum Annual Yield from Table A.4	Ball L.* (50% of Fish Capability)	Indian L.* (50% of Fish Capability)	Total (rounded)
		(kilograms per year)		
Total Commercial Catch	47,390	4,033	3,143	54,600
Northern Pike	13,549	404	472	14,400
Walleyes	20,485	807	754	22,100
Whitefish	5,829	807	723	7,400
Tullibee	12,423	N/A	N/A	12,400

* From Table A.3

TABLE A.7

ESTIMATED FINANCIAL VALUES OF POTENTIAL ANNUAL INCREASED COMMERCIAL FISH CATCHES FROM THE WABIGOON-ENGLISH-WINNIPEG RIVER SYSTEMS

Species	Average (Ontario-wide) Prices 1981	Total Annual Revenues Based on Mean Potential Fish Yield (Table 5.3)		Total Annual Revenues Based on Maximum Annual Catches (Table 5.3) Plus 50% of Potential Yields on Ball and Indian Lakes	
	($ per kg)	kg	($ 1981)	kg	($ 1981)
Northern Pike	$ 1.21	8,900	$ 10,770	14,400	$ 17,424
Walleye Pike	3.55	12,400	44,020	22,100	78,455
Whitefish	1.76	1,300	2,290	7,400	13,024
Tullibee	1.23*	1,500	1,850	12,400	15,252
		24,100	58,930	56,300	124,155
Total Yield		28,900		**	
Difference	1.23	4,800	5,904	-	-
Total Revenue			$ 64,826		$124,155

* There are no "Ontario-wide" average revenue data for Tullibee. Therefore, average revenues for "total yield" is applied.

** The maximum "total yield" for a given year is less than the sum of the maximum total yields for each species.

APPENDIX B

DETAILED COST ESTIMATES OF DREDGING THE WABIGOON RIVER BETWEEN DRYDEN AND CLAY LAKE

TABLE B.1

COST COMPONENTS OF DREDGING THE WABIGOON RIVER BETWEEN DRYDEN AND CLAY LAKE

Cost Items	Equipment	Labour ($ million)	Other	Total
Disposal Site development*	-	1.6	-	1.6
Trunk Pipeline (12 km)	.7	-	-	0.7
Moving Pipeline	-	1.1	-	1.1
Dredging Machinery	1.0	-	-	1.0
Dredge Connecting Pipelines (1 km/dredge)	.4	-		0.4
Sub-total	2.1	2.7	-	4.8
Booster stations	.5	-	-	0.5
Fuel	-	-	.8	0.8
Labour	-	3.6	.5	3.6
Field camp	-	-	-	0.5
Pontoon and work boats	.5	-	-	0.5
Log clearing equipment	1.0	0	0	1.0
Engineering and management	-	-	1.0	1.0
Sub-total	2.0	3.6	2.3	7.9
Total estimated cost	4.1	6.3	2.3	12.7
Contingency allowance (50%)**				6.3
GRAND TOTAL				19.0

* Seven disposal sites are proposed.

** In a project of this nature, some unanticipated work should be allowed for. This might include difficulties with submerged logs, a need for more extensive development work with the cutterhead and control system or constraints on disposal site development. Because of these and other uncertainties, a contingency allowance has been included. Acres argues that there is sufficient experience to justify a contingency allowance as low as 20%. However, to be "conservative", a 50% contingency allowance is recommended by Acres.

Source: Acres Consulting Services Limited, Studies on Moving Sediments in the Wabigoon River for Ontario Ministry of the Environment, 1982, P. 75.

TABLE B.2

EXPECTED ANNUAL COST OUTLAYS FOR DREDGING THE WABIGOON RIVER FROM DRYDEN TO CLAY LAKE

Year	Items	Costs ($1981)
1	Field studies	370,000
	Administration	12,000
	Total for Year	$ 392,000
2	Field studies	30,000
	Dredge testing	80,000
	Environmental Assessment studies	10,000
	Administration	36,000
	Total for Year	$ 296,000
3	Implementation	4,750,000
	Monitoring	100,000
	Mapping	37,500
	Clay Lake Survey	25,000
	Administration	60,000
	Total for Year	$ 4,972,500
4	Implementation	4,750,000
	Monitoring	100,000
	Mapping	37,500
	Administration	60,000
	Total for Year	$ 4,947,500
5	Implementation	4,750,000
	Monitoring	100,000
	Administration	60,000
	Total for Year	$ 4,910,000
6	Implementation	4,750,000
	Monitoring	100,000
	Administration	60,000
	Total for Year	$ 4,910,000
	GRAND TOTAL	$20,428,000

Source: Acres (1982), pp. 120-121.

APPENDIX C

RECENT COMPENSATION SETTLEMENTS AND DECISIONS ABOUT REMEDIAL MEASURES

As this report was being finalized, two important developments occurred which partially resolved this issue.

First, after years of negotiation, compensation settlements were reached among the Grassy Narrows and Islington Bands and the paper companies, the Ontario government and the federal government. The negotiations were mediated by Justice Emmett Hall. The elements of the agreement, which was ratified by the two Bands in December 1985, are as follows (Toronto Star, Dec. 9, 1985; Toronto Star, Dec. 12, 1985):

(a) Compensation awards to both Bands from:

Ontario	\$2.167 million
Federal government	\$2.75 million
Reed Paper Ltd.	\$5.75 million
Great Lakes Forest Products	\$6 million

(b) Health disability claim fund — \$2 million

In addition, the two Bands have won other compensatory awards.

(a) Federal cash settlements:

- Grassy Narrows - \$4.4 million
- Islington (Whitedog) - \$1.5 million

(b) Compensation from Ontario Hydro for flooding of Islington Band reserve land

- cash	\$1.5 million
- land	1,700 hectares
- lake clean-up fund	employs 30 Band members per year

(c) Community development projects sponsored by the provincial government:

- greenhouse project,
- community centres,
- purchase hunting, trapping and fishing equipment.

The Grassy Narrows Band is planning to purchase Ball Lake Lodge out of thse proceeds.

Dredging or other rehabilitation measures recommended by the federal/provincial Steering Committee were not mentioned in these agreements.

Early in 1985, a senior federal/provincial technical review committee, which included representatives from interested provincial and federal ministries, reviewed the technical reports and the Steering Committee's recommendations. In June 1985, the review committee recommended that dredging not be implemented and that the river systems be left to natural recovery. The review committee also recommended that the pilot project for resuspension of non-contaminanted sediment be deferred for the time being. These recommendations were subsequently accepted by the federal and provincial Environment Ministers.

The decision to reject the dredging option, together with the provision of more direct compensation and development assistance for the two Native Communities, is consistent with the conclusions and recommendations of the present study.